CORPS OF ENGINEERS, U. S. ARMY

CONDUITS AND HOWELL-BUNGER VALVES
NARROWS DAM, LITTLE MISSOURI RIVER, ARKANSAS

MODEL INVESTIGATION

TECHNICAL MEMORANDUM NO. 2-294

WATERWAYS EXPERIMENT STATION

VICKSBURG, MISSISSIPPI

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PREFACE

A model study of the conduits and Howell-Bunger valves for Narrows Dam was authorized by the Chief of Engineers in the third indorsement, dated 19 August 1948, to a letter from the Division Engineer, Lower Mississippi Valley Division, to the Chief of Engineers, dated 4 April 1946, subject: "Specifications and Drawings for Narrows Dam." The study was accomplished during the period March 1947 - April 1948 at the Waterways Experiment Station for the Division Engineer, Lower Mississippi Valley Division.

During the course of the study Messrs. E. J. Williams, Jr., J. E. Sanders, C. L. Sumrall, Jr., and F. B. Toffaleti, engineers of the Lower Mississippi Valley Division, visited the Experiment Station at frequent intervals to discuss the testing program and to correlate test results with design and construction work concurrently being accomplished. The study was conducted in the Hydraulics Division of the Waterways Experiment Station by Messrs. C. Kestenbaum and W. H. Sadler, Jr., under the general supervision of Messrs. F. R. Brown and T. E. Murphy.

Results of a previous model study on the spillway stilling basin for Narrows Dam are contained in Technical Memorandum No. 209-1, "Model Study of Stilling Basin, Narrows Dam, Little Missouri River, Arkansas," revised 1 October 1944.

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SUMMARY

The purpose of this investigation was to examine the over-all performance of the conduits and 84-in. Howell-Bunger valves to be used to regulate flow through the outlet conduits of Narrows Dam, with particular attention to discharge coefficients, velocities in the exit area, and pressures on the end sill of the stilling basin.

Tests, which were conducted on a 1:16-scale model, demonstrated the need for some type of hood over the valves to prevent flow from being projected onto the access road along the right side of the stilling basin. Hoods having semicircular tops of 8.75-ft radius supported by vertical walls from the basin floor gave satisfactory results. The coefficient of discharge for the combination of the valves without the hoods and the contraction immediately above the valves was found to vary between 0.87 and 0.88. The use of a hood on the valves did not impair the discharge capacity. It was necessary to replace the sloping end sill of the original design with a vertical-faced end sill to maintain a cushion of water in the stilling basin. Pressures on the end sill were not of serious proportions.

CONDUITS AND HOWELL-BUNGER VALVES

NARROWS DAM, LITTLE MISSOURI RIVER, ARKANSAS

Model Investigation

PART I: INTRODUCTION

The Prototype

1. Narrows Dam, which was designed by the Fargo Engineering Company for the Division Engineer, Lower Mississippi Valley Division, is located on the Little Missouri River, a tributary of the Ouachita River, in southwestern Arkansas. Figure 1 is a vicinity map of the area. The dam is of the concrete-gravity type and has an over-all length of about 940 ft and a maximum height of about 185 ft. The reservoir created by the dam has a maximum capacity of 408,000 acre-ft, of which 128,000 acre-ft is to be used for flood control and 280,000 acre-ft (including 78,000 acre-ft of dead storage) is to be used for generation of hydroelectric power. The general layout of the dam is shown on plate 1.

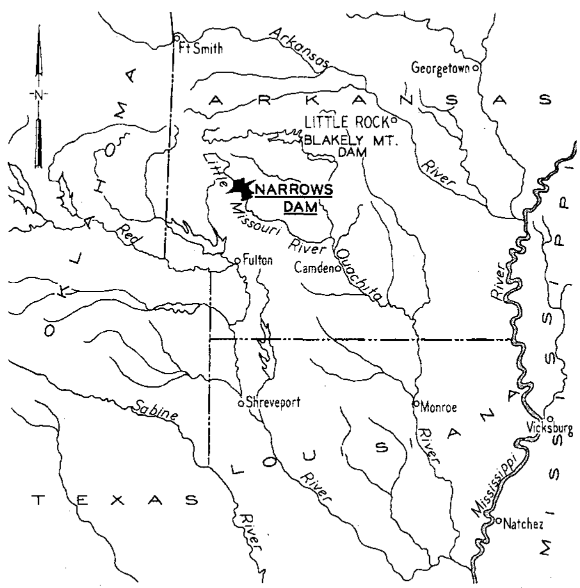

Figure 1. Vicinity map

2. Normal flow regulation is afforded by two 84-in. Howell-Bunger valves on the downstream end of two 8.5-ft-diameter conduits.

Details of a conduit and valve are shown on plates 2 and 3. The combined capacity of these valves is about 5,000 cfs at pool elevation 548 (maximum power pool).

3. An uncontrolled concrete overflow spillway section with its crest at elevation 563* is located in an interior portion of the dam. The spillway crest is 150 ft long and is designed to pass a maximum discharge of 42,000 cfs under a head of 17 ft.

4. Three 10.0-ft-diameter steel-lined penstocks have been provided for generation of power, and two vertical-type turbine units have been installed. The third penstock, provided for future use if required, has been sealed at each end by temporary concrete bulkheads.

Need for and Purpose of Model Analysis

5. Little was known about the action of a stilling basin downstream from large Howell-Bunger valves. It was feared that there might be considerable energy concentrated at certain points downstream from the stilling basin resulting from the intersection of the jets from the two valves and from waves set up by the side walls. Also, with high velocities over the end sill, cavitation on the top of the sill was considered possible. Further, conclusive data on the discharge coefficient for a Howell-Bunger valve were not available. Therefore a model study was authorized to examine the over-all performance of the conduits and Howell-Bunger valves with particular attention directed to the questions enumerated above.

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* All elevations are in feet above mean sea level.

The Model

6. The investigation was conducted on a model built to a scale ratio of 1:16 (figure 2). There were reproduced in the model the entire conduits including the intakes and Howell-Bunger valves, the stilling basin, and approximately 250 ft of the exit channel. The reservoir area was represented by a steel pressure tank of sufficient size and properly baffled to provide quiet approach conditions. The intakes and conduits were fabricated of transparent plastic, while the Howell-Bunger valves were machined in steel (figure 3). The stilling basin and exit channel were molded in cement mortar.

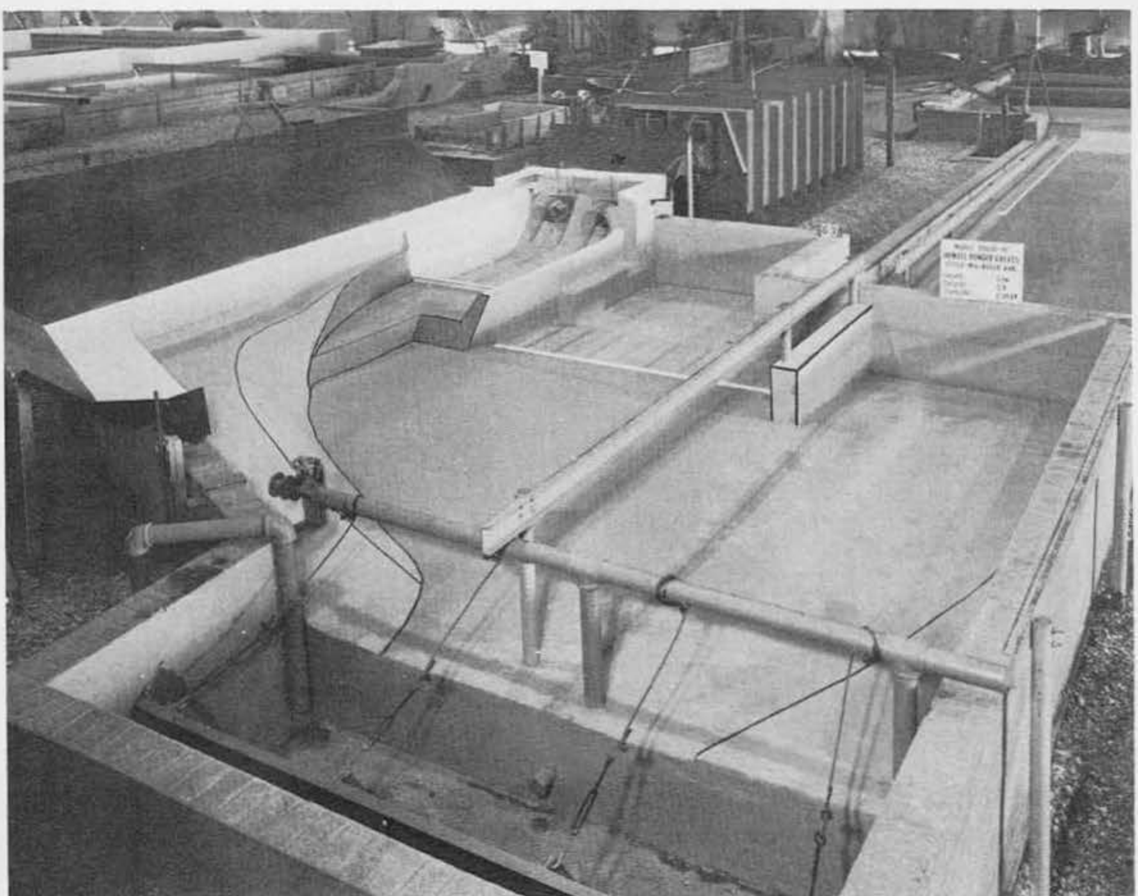
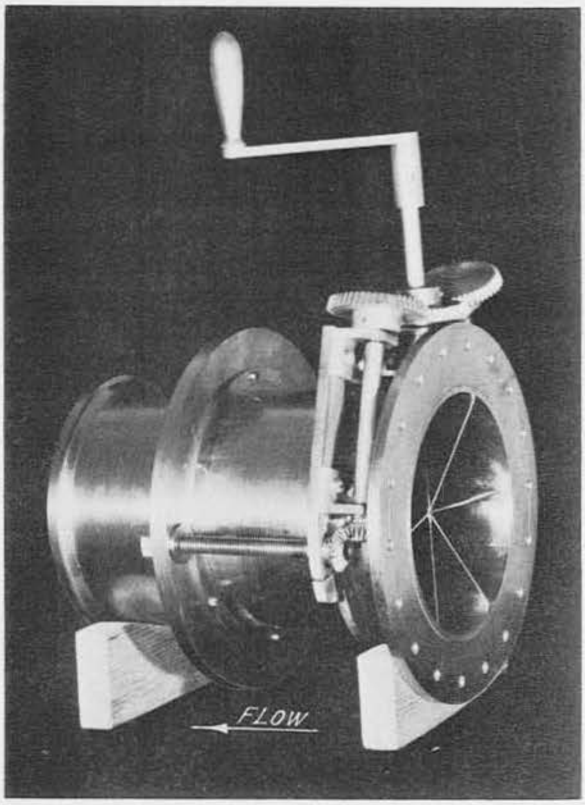


Figure 2. General view of the model



Closed position

Open position

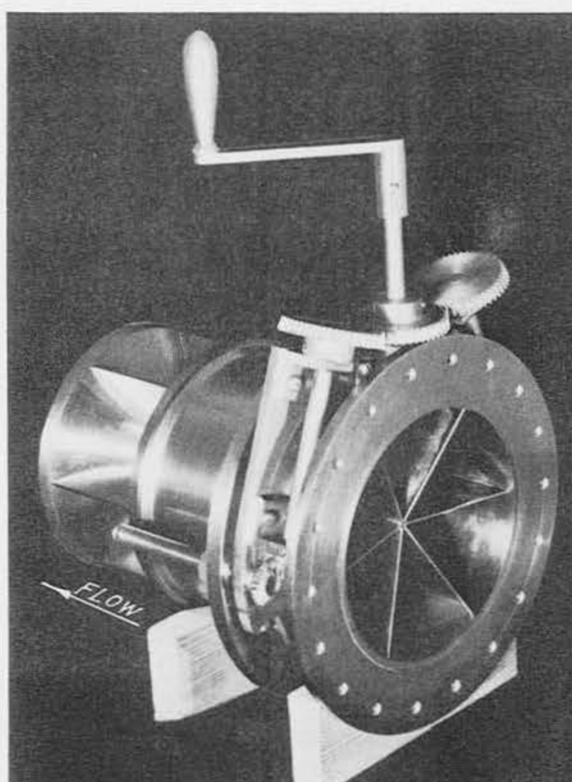


Figure 3. Model valve

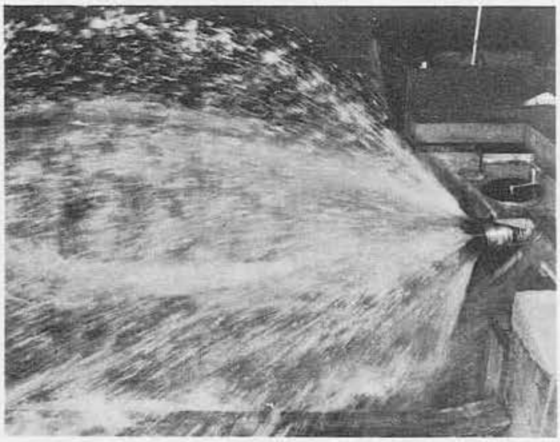
PART II: NARRATIVE OF TESTS

7. Tests were conducted with the reservoir at three elevations: minimum power pool, 504; maximum power pool, 548; and spillway crest, 563. Tailwater elevations were set in accordance with the improved channel tailwater rating curve shown on plate 4. During the course of the study investigations were made of the valves discharging free and with four hood designs confining the flow from the valves to the stilling-basin area. Details of the hoods are shown on plate 5. Six modifications to the stilling basin and exit area, details of which are shown on plate 6, were tested.

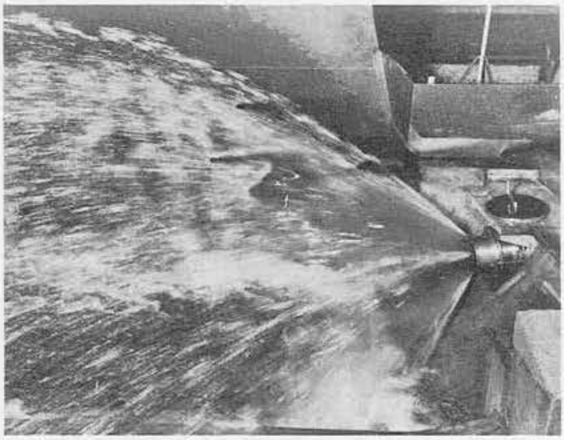
Valves Discharging Free, Original Design Basin

8. Flows from the valves discharging free into the stilling basin of original design (plate 6) are shown by figure 4. It was found that even with the pool at elevation 504, flow from the right valve was projected onto the access road along the right side of the stilling basin. Also, it was found that the trajectory of the flow from the valves was dependent upon the pool elevation and was changed very little by changes in the valve opening. Another item of interest noted during the initial tests was the fins of water on the main jet caused by the metal ribs in the valve. At first it was thought that this might be a model condition which would not occur in the prototype. However, it was found that similar fins of water were produced by the ribs of the 60-in. valves at Nimrod Dam, Arkansas.

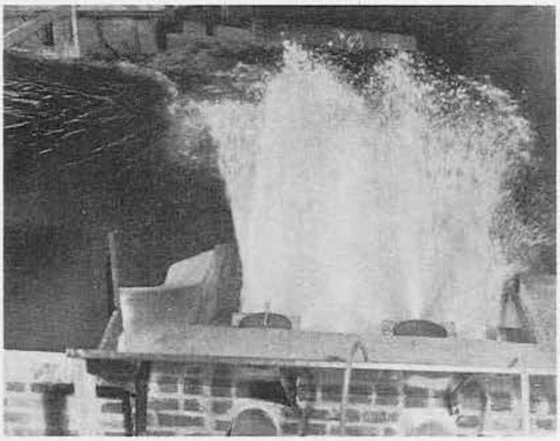
9. Positive pressures existed throughout the sluice. Table 1



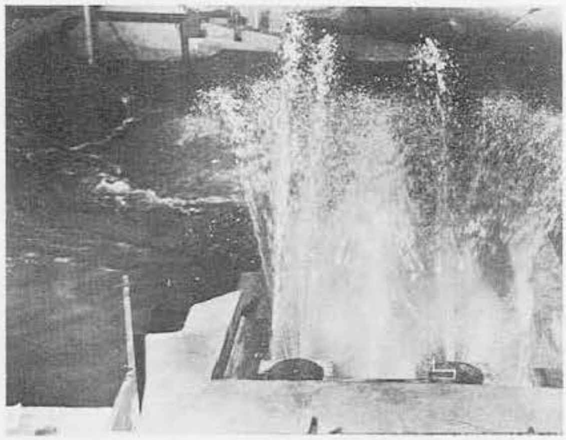
Valve full open; pool 563
Discharge 2665 cfs



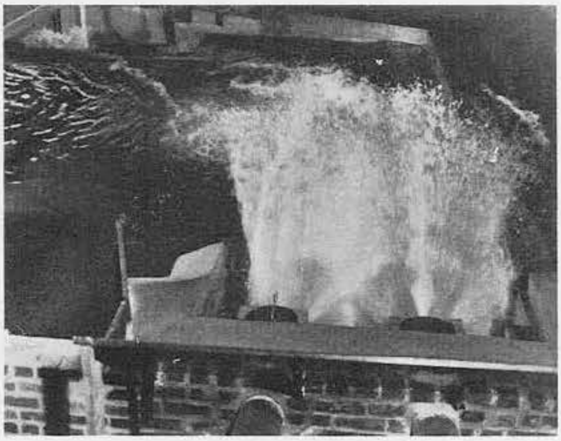
Valve one-quarter open; pool 563
Discharge 980 cfs



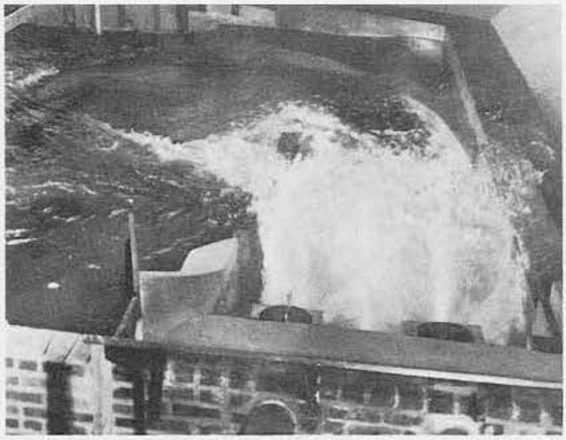
Valves full open; pool 563
Discharge 5330 cfs



Valves one-quarter open; pool 563
Discharge 1960 cfs



Valves full open; pool 548
Discharge 5035 cfs



Valves full open; pool 504
Discharge 4064 cfs

Figure 4. Flow conditions, valves discharging free. Original design

lists pressures measured, while piezometer locations are shown on plate 7. Also, it was found that pressures on the top of the end sill were not of a serious nature since the minimum pressure measured was only -1.0 ft of water.

10. A straight horizontal section of conduit was used for studies to determine the discharge coefficient of the Howell-Bunger valves. The valve was connected first to a 102-in.-diameter conduit with a transition immediately upstream from the valve to simulate the Narrows Dam conditions. Additional tests were conducted with the transition eliminated and an 84-in.-diameter conduit, the same diameter as the valve. With the valve at full opening, the coefficient of discharge for the above two conditions varied from about 0.87 to 0.88 (plates 8 and 9). With the 102-in.-diameter conduit, the coefficient of discharge was based on a piezometer just upstream from the transition and on one in the transition 2 ft upstream from the valve. Coefficients based on the latter piezometer are believed to be affected somewhat by the curvature of flow in the transition. The coefficient of discharge was about 0.88 (plate 9) with the transition eliminated and the 102-in.-diameter conduit replaced with one the same size as the valve. Comparison of plates 8 and 9 indicates that the loss through the transition is negligible. Plate 10 shows the variation in discharge coefficient as the valve is closed. Full opening of the valve is referred to the maximum travel of the outer sleeve which at Narrows Dam was limited by the operating machinery. The maximum travel was only about 95 per cent of the travel necessary to place the outer sleeve in the fully retracted position. All coefficient values were computed from the equation, $C = Q/A\sqrt{2gH}$, where C is the coefficient of discharge, Q

is the discharge, A is the area of an 84-in. circle, and H is the total head at the control piezometer.

11. Head-discharge relations for Narrows Dam conditions were computed on the basis of the valve coefficient data presented on plate 10 and the pressure data in table 1. Head-discharge plots with the valve set at 1/4, 1/2, 3/4, and full openings are shown on plate 11. These data vary slightly from the information presented in the title of the photographs of flow conditions. The difference is caused by the use of a more schematic-type valve during tests with the general model. The valve coefficient data and the computed head-discharge curves were based on an accurately constructed valve.

12. A few prototype measurements have been made on one of the valves at Narrows Dam subsequent to the model studies. Data obtained thus far are in general agreement with the valve coefficient data shown on plate 10. However, actual discharge measurements for the conduit and valve appear to be less than the computed values presented on plate 11. Additional prototype measurements are scheduled and will be the subject of a subsequent report.

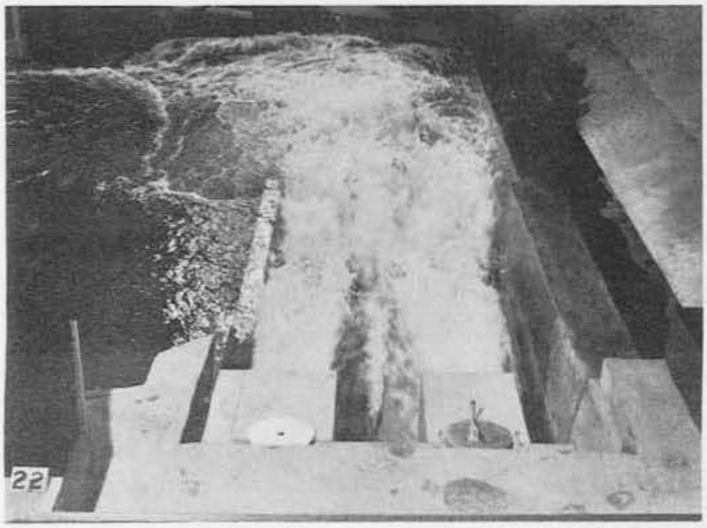
Hooded Valves, Original and Modified Basins

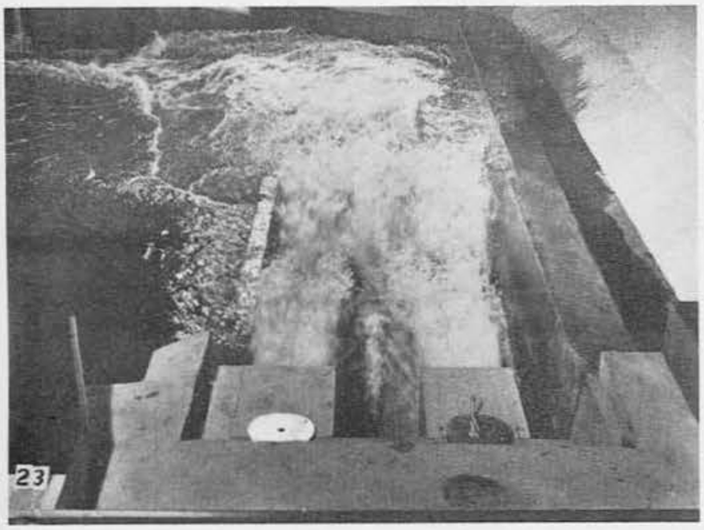
Type 1 hoods -- original exit area

13. Anticipating objectionable spray from the valves, the Fargo Engineering Company designed rectangular hoods to be placed over the valves for the purpose of confining flow to the stilling-basin area. General details of these hoods, which are listed as the type 1 hoods in this report, are shown on plate 5.

14. Flows from the type 1 hoods are shown by figure 5. While the

Pool 563
Discharge 5500 cfs





Pool 548
Discharge 5190 cfs

Pool 504
Discharge 4090 cfs

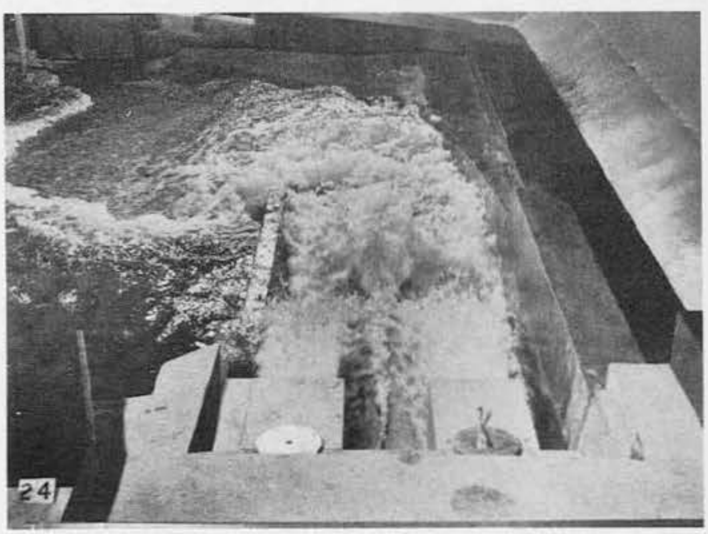


Figure 5. Flow conditions, type 1 hoods

type 1 hoods confined flow to the stilling area, they also caused concentrations of flow off the sides of the hoods. Flow swept through the stilling basin and into the exit area with very little energy being dissipated in the stilling basin. Use of the valve hood did not impair the capacity of the valve; in fact a small increase in discharge capacity was noted.

Type 2 hood -- original exit area

15. The type 2 hoods consisted of circular tubes 17.5 ft in diameter. The valve was placed in the lower portion of the tube offset 1.75 ft from the center. See plate 5 and figure 6. Air vents were provided to the rear of the tube.

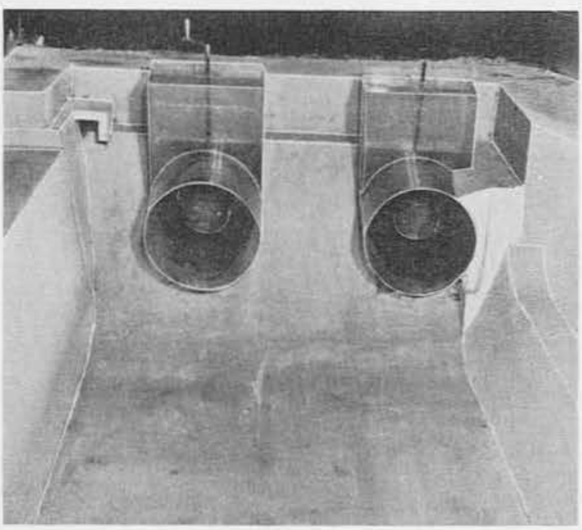


Figure 6. Type 2 hoods

16. With the type 2 hood installed flow distribution at the end sill appeared to be improved but flow still swept through the stilling basin and into the exit area with very little energy dissipated in the stilling basin.

Type 2 hoods -- type 2 exit area

17. In an effort to obtain more energy dissipation in the stilling basin the 4-ft-high sloping end sill was replaced by a 4-ft-high vertical end sill. From observations of flow with the end sill at several locations it was determined that the optimum location for the 4-ft-high vertical end

sill was at a distance of 222 ft from the axis of the dam. Also, the left wall of the stilling basin was extended 20 ft to prevent currents from attacking the exit area at the base of the end sill of the spillway stilling basin. A profile of the type 2 exit area is shown on plate 6.

Pool 563; discharge 5475 cfs

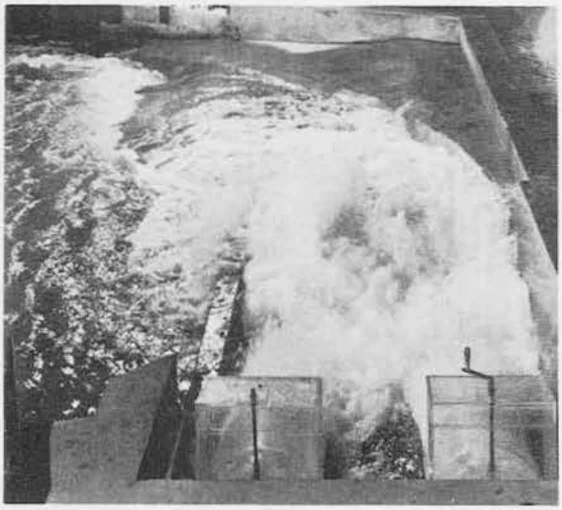
Figure 7. Flow conditions, type 2 hoods, type 2 exit area

18. The 4-ft-high vertical end sill caused a cushion of water to remain in the stilling basin (figure 7). However, the configuration of the rock in the exit area caused currents to sweep laterally in front of the spillway stilling basin and into the power tailrace (plate 12).

Type 2 hoods -- type 3 exit area

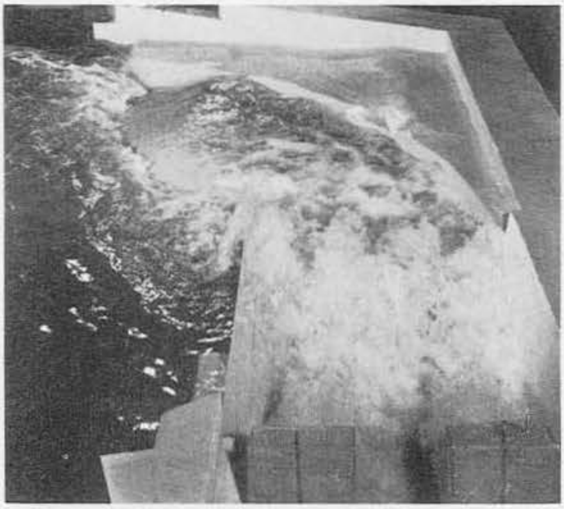
19. All rock in the exit area above elevation 410 was removed in order to reduce the lateral currents downstream from the spillway stilling basin. Also the end sill height was increased to 6 ft. A profile of type 3 exit area is shown on plate 6.

20. Although velocities as high as 30 ft per sec were measured in the type 3 exit area, these high velocities generally were confined to the right side of the channel and a slow eddy was formed in the



Pool 563; discharge 5475 cfs

Figure 8. Flow conditions; type 2 hoods, type 3 exit area



Pool 563; discharge 5475 cfs

Figure 9. Flow conditions, type 3 hoods, type 3 exit area

power tailrace. See figure 8 and plate 13.

Type 3 hoods -- type 3 exit area

21. The type 3 hoods were identical to the type 2 except that for type 3 the 17.5-ft-diameter tubes were placed concentrically with the valves (plate 5). With this alteration, impact on the end sill seemed to be lessened and flow distribution across the end sill improved (compare figures 8 and 9). However velocities in the exit area were not changed materially (compare plates 13 and 14).

Type 4 hoods -- type 3 exit area

22. Although the type 3 hood appeared satisfactory, engineers of the Lower Mississippi Valley Division desired for structural reasons to use a hood having a semicircular top supported by vertical walls from the basin floor. Details of this hood, the type 4, are shown on plate 5, while figure 10 is a view of the hoods in the model. As in the types 2

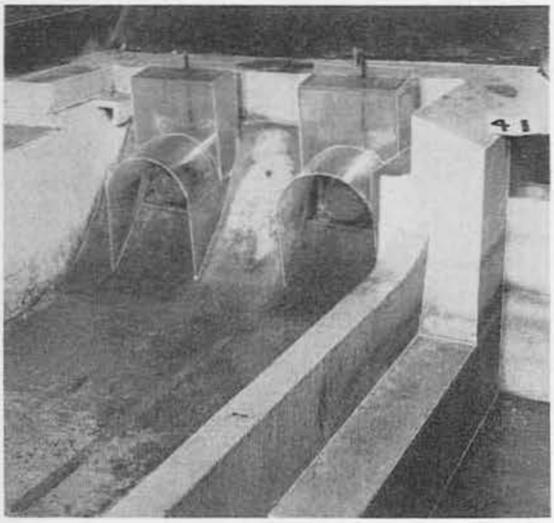
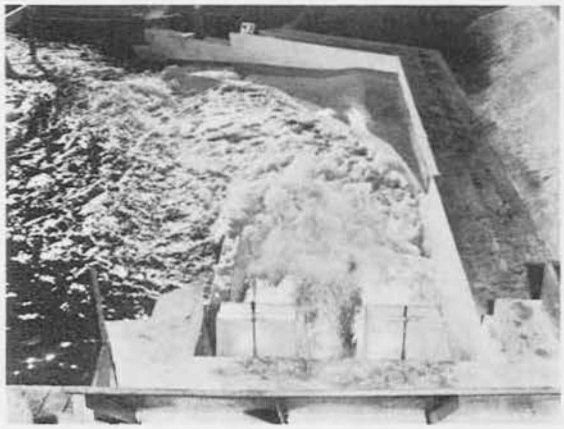


Figure 10. Type 4 hoods



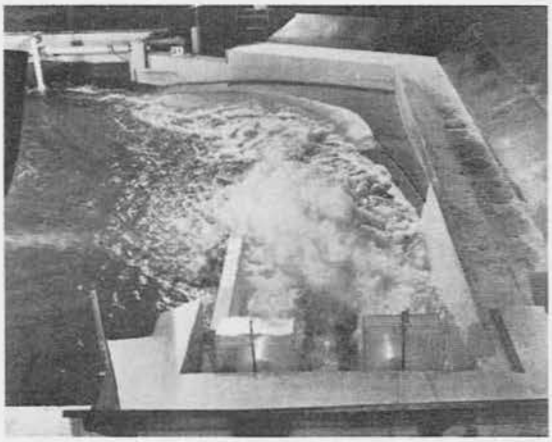
Pool 563; discharge 5440 cfs

Figure 11. Flow conditions, type 4 hoods, type 3 exit area

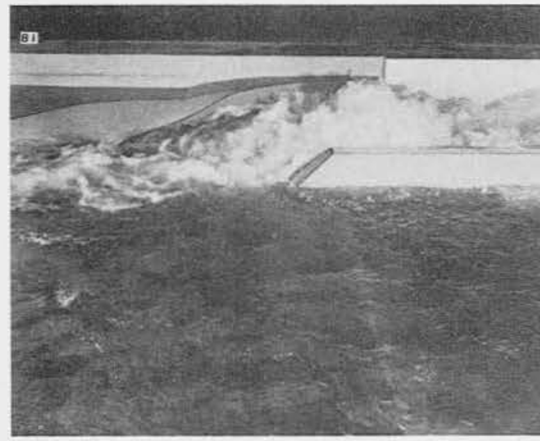
and 3 hoods air vents were provided to the rear of the hoods. The type 4 hoods produced flow conditions in the stilling basin and exit area similar to those produced by the type 3 hoods. Compare figure 9 and figure 11, and plates 14 and 15. Discharge capacity of the valves was not impaired by use of any of the hoods investigated.

Type 4 hoods -- types 4-6 exit areas

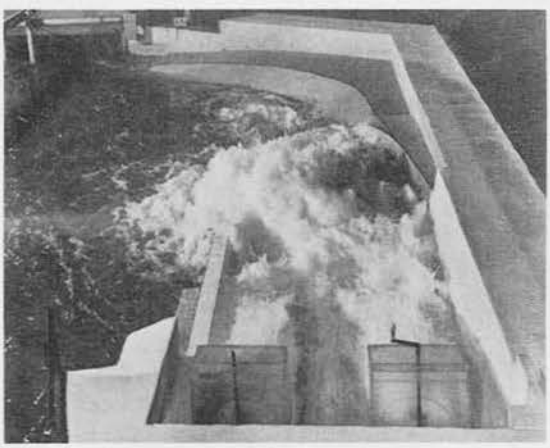
23. At this stage of the testing program the Lower Mississippi Valley Division informed the Waterways Experiment Station that foundation conditions were such as to make it desirable to lower the stilling basin 2 ft to elevation 404. Also it was explained that steel had been ordered for construction of a stilling basin which would extend a distance of 215 ft downstream from the axis of the dam and that it would be desirable to terminate the basin at this point. The types 4, 5 and 6 exits involved horizontal aprons at elevation 404, extending downstream 215 ft from the axis of the dam, and terminated by vertical end sills



Type 4 exit area

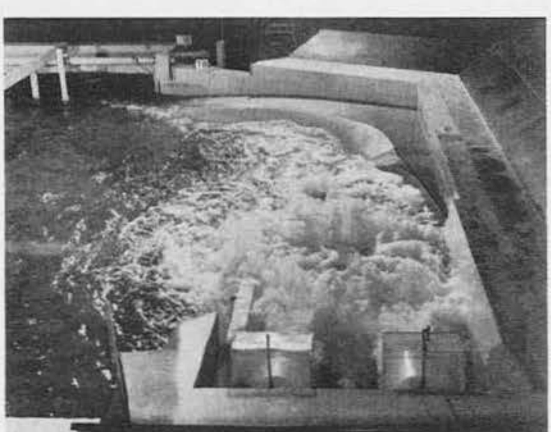


Type 4 exit area

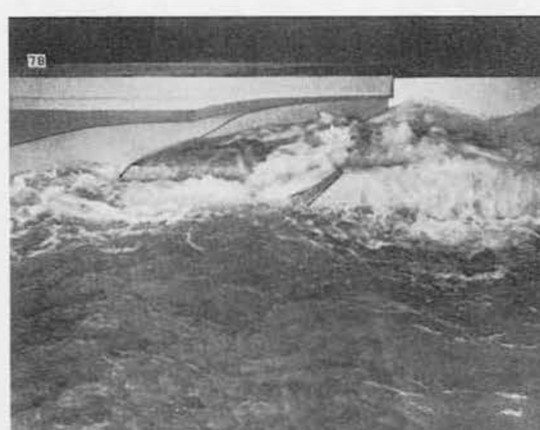


Type 5 exit area

Type 5 exit area



Type 6 exit area



Type 6 exit area

Figure 12. Flow conditions, type 4 hoods, types 4-6 exits.
Pool elevation 563; discharge 5440 cfs

6, 8 and 10 ft high, respectively (plate 6).

24. Figure 12 shows flow conditions in the types 4, 5 and 6 exits, while velocities produced in the exit area are shown on plates 16, 17 and 18, respectively. Of these three exits the type 5 produced the least turbulence at the end sill and the lowest velocities over and immediately downstream from the end sill. For these reasons the type 5 exit area was recommended for construction in the prototype. For record purposes, additional photographs of flow from the type 4 hoods into the type 5 exit are included as an Appendix hereto.

Type 4 hoods with wedge

25. The Office, Chief of Engineers, proposed that wedges, as shown by figure 13, be installed on the roofs of the hoods to split the issuing flow and allow air to reach the centers of the jets. These wedges did split the flow and allowed air passages to the centers of the jets but did not produce noticeable effects on discharges, pressures, or flow conditions. Thus the wedges were not considered necessary with the type 4 hoods.

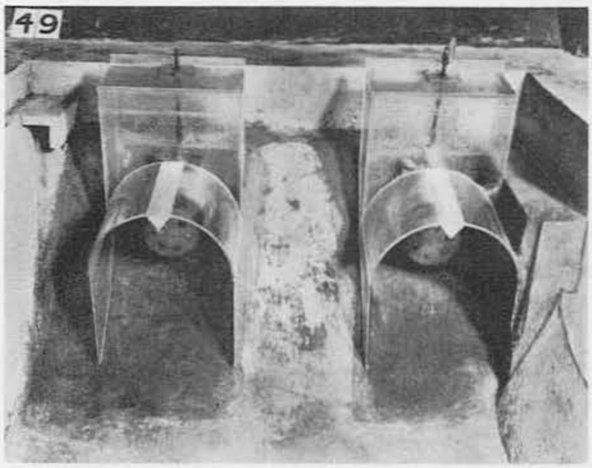
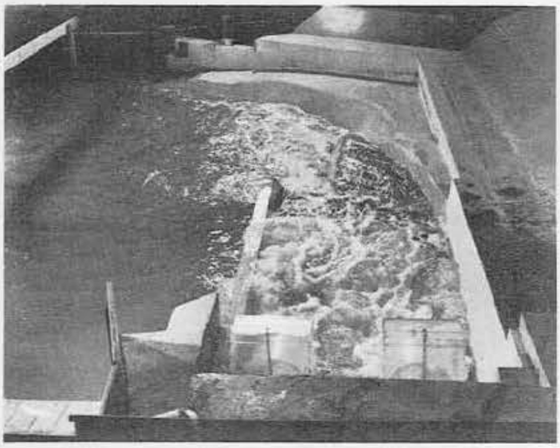


Figure 13. Type 4 hoods with wedges

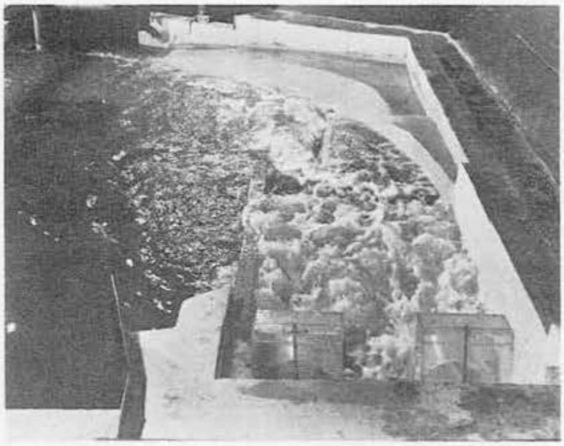
Diversion Flows

26. During construction of Narrows Dam it was planned to pass flow through the conduits with the Howell-Bunger valves removed. Figure 14

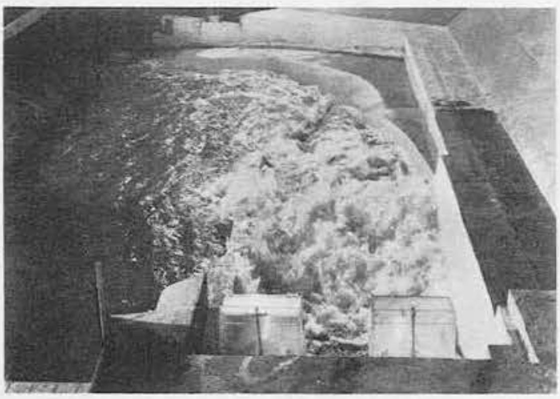
shows flow conditions in the stilling basin and exit area produced by flows through the conduits without Howell-Bunger valves. Plate 19 is a rating curve for diversion conditions. These flows produced no conditions likely to endanger the prototype structure.



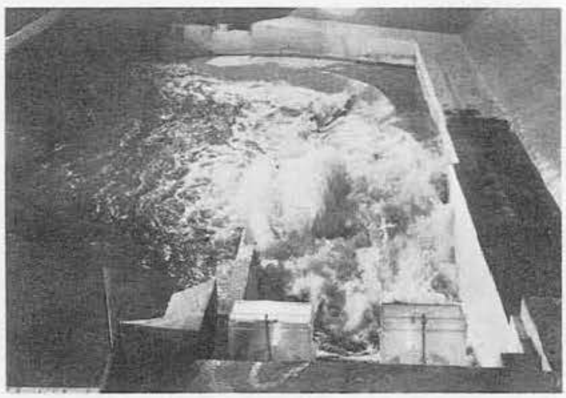
Pool 465; discharge 3510 cfs



Pool 480; discharge 4160 cfs



Pool 504; discharge 5050 cfs



Pool 548; discharge 6350 cfs

Figure 14. Diversion flows, valves removed

PART III: DISCUSSION

27. The most satisfactory design as developed from the model study includes valve hoods having semicircular tops, concentric with the valves, supported by vertical walls from the basin floor (type 4 hoods, plate 5). The stilling-basin floor is at elevation 404 and is terminated by an 8-ft-high, vertical-faced end sill located 215 ft downstream from the axis of the dam (type 5 exit, plate 6). It is the opinion of the Waterways Experiment Station that this arrangement gives as satisfactory performance as can be expected without making major changes in the arrangement of the structures.

28. The discharge coefficient for the combination of the valve and the contraction immediately above was found to be about 0.875. The addition of the valve hood caused a slight increase in the discharge coefficient.

29. It is felt that the necessity for placing hoods over Howell-Bunger valves creates an undesirable feature in that it detracts from the energy dissipating characteristics of the valve. However, the hoods were necessary, for the case at hand, to prevent flow from being projected onto the access road along the right side of the stilling basin, and to confine all spray to the stilling-basin area.

TABLE

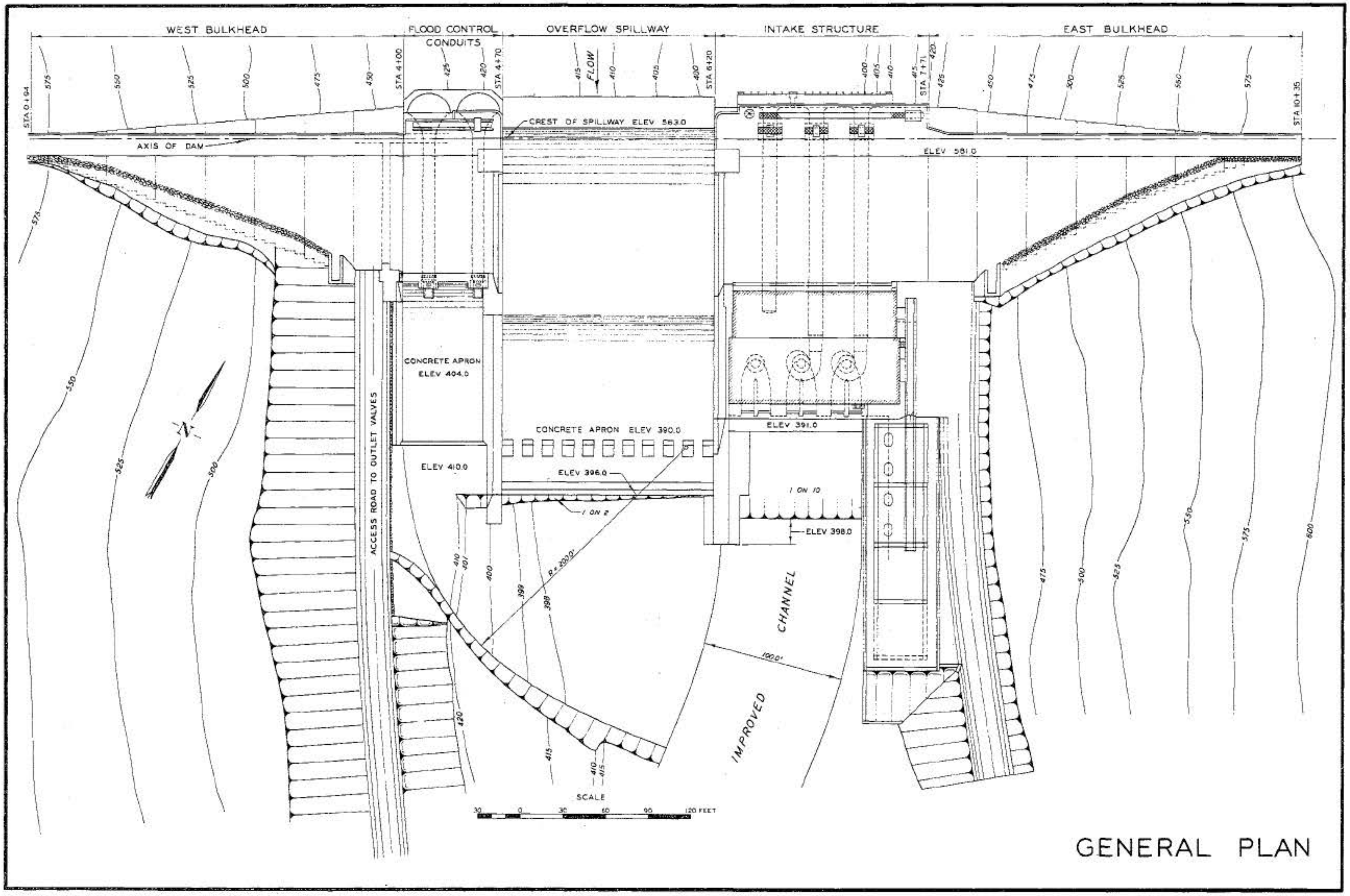
Table 1

PRESSURES IN CONDUIT -- NO VALVE HOOD

Piez. No.	Piez. Zero	Pressures (in prototype ft of water) Pool elevation 563 Discharge -- 2665 cfs	Pool elevation 548 Discharge -- 2518 cfs	Pool elevation 504 Discharge -- 2032 cfs
1	458.2	105.0	89.2	45.8
2	456.0	106.8	91.6	48.0
3	448.8	108.3	95.5	53.0
4	446.6	100.9	89.0	50.4
5	445.5	87.8	78.2	44.4
6	438.6	85.4	75.4	46.3
7	435.3	89.1	78.1	50.4
8	432.1	91.7	80.7	52.8
9	429 1	93.4	82.1	55.3
10	427.4	85.3	77.3	51.4
11	426.6	60.0	54.8	36.5

NOTE: Locations of piezometers are shown on plate 7.

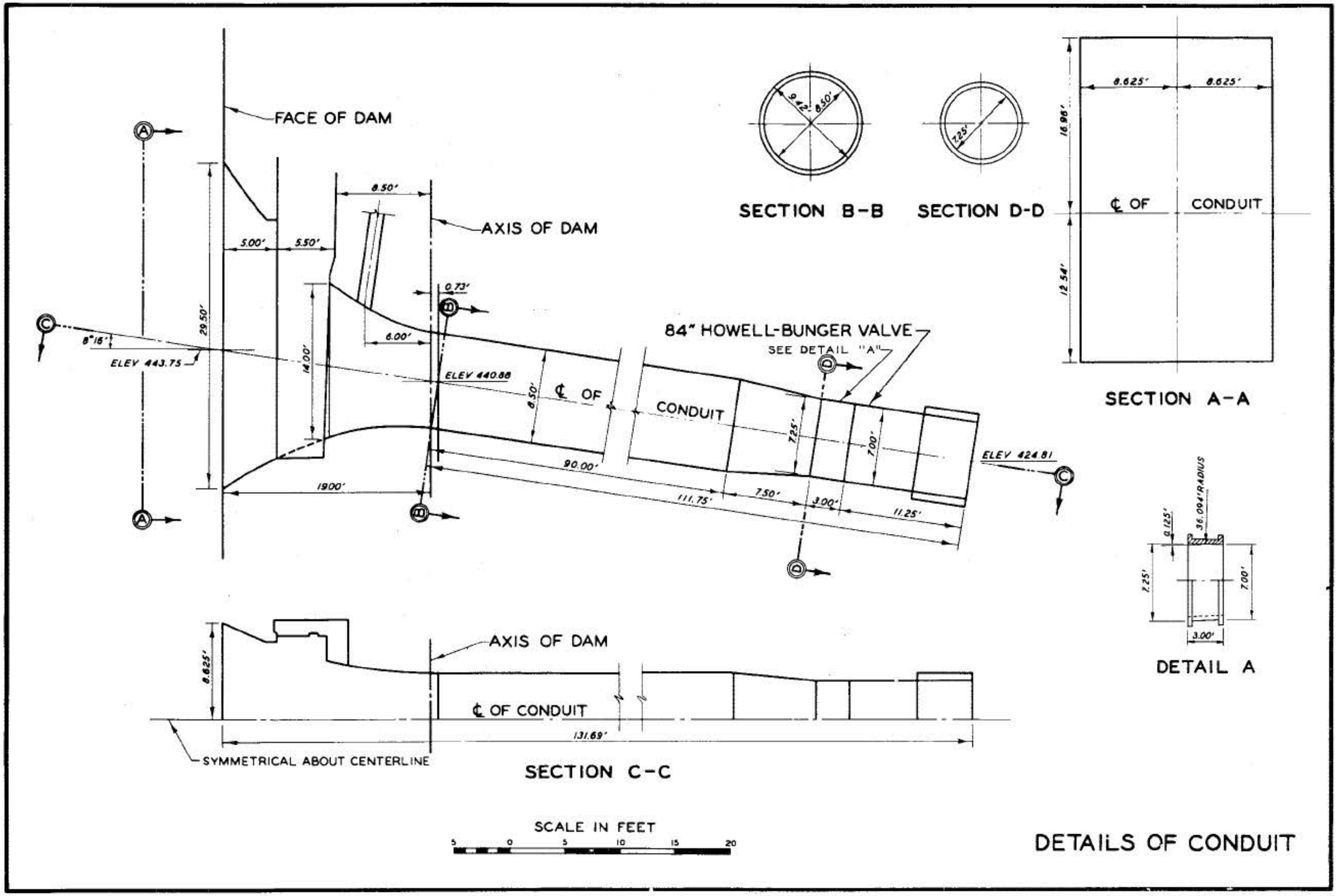
PLATES



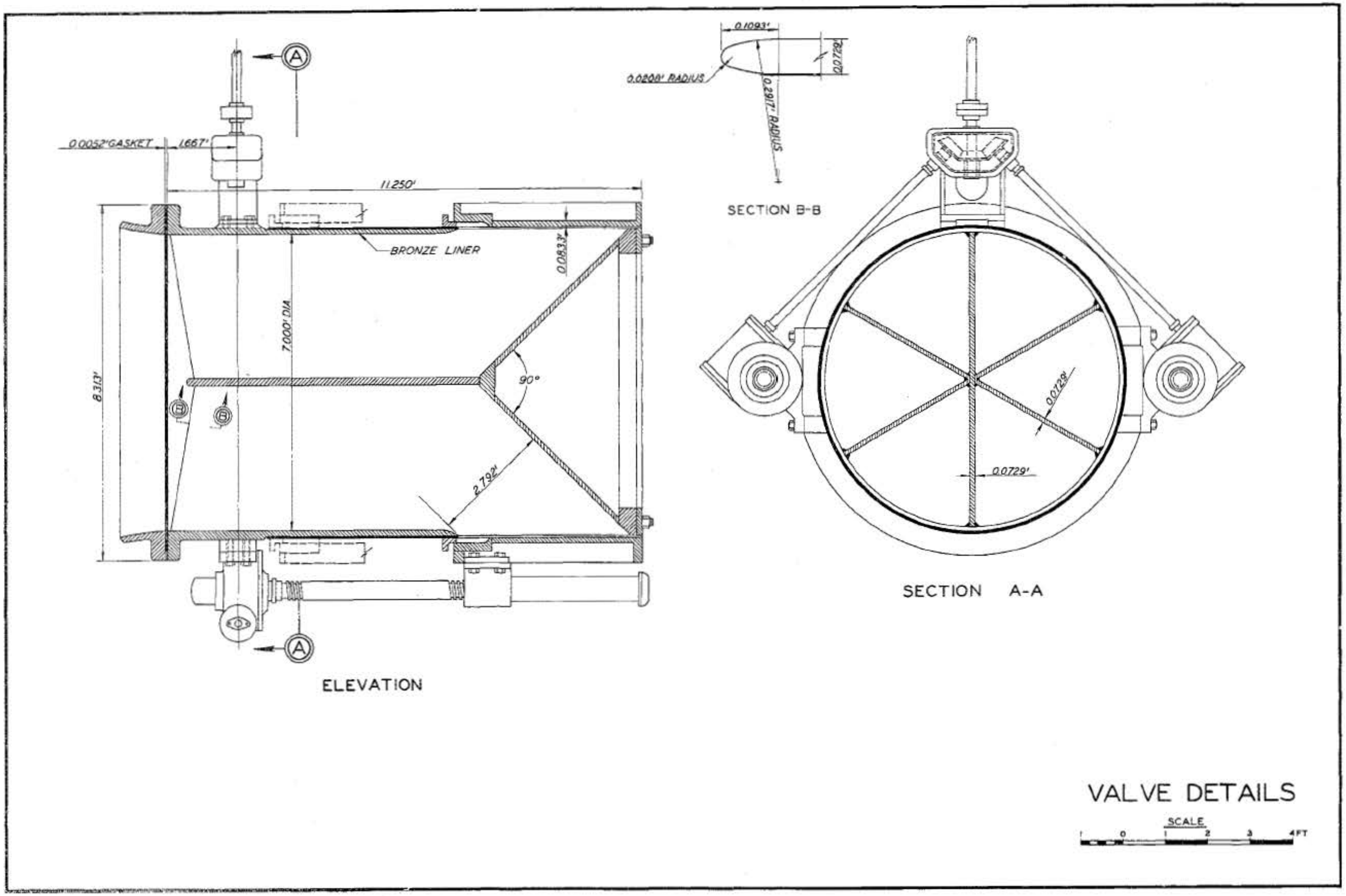
GENERAL PLAN

PLATE I

PLATE 2



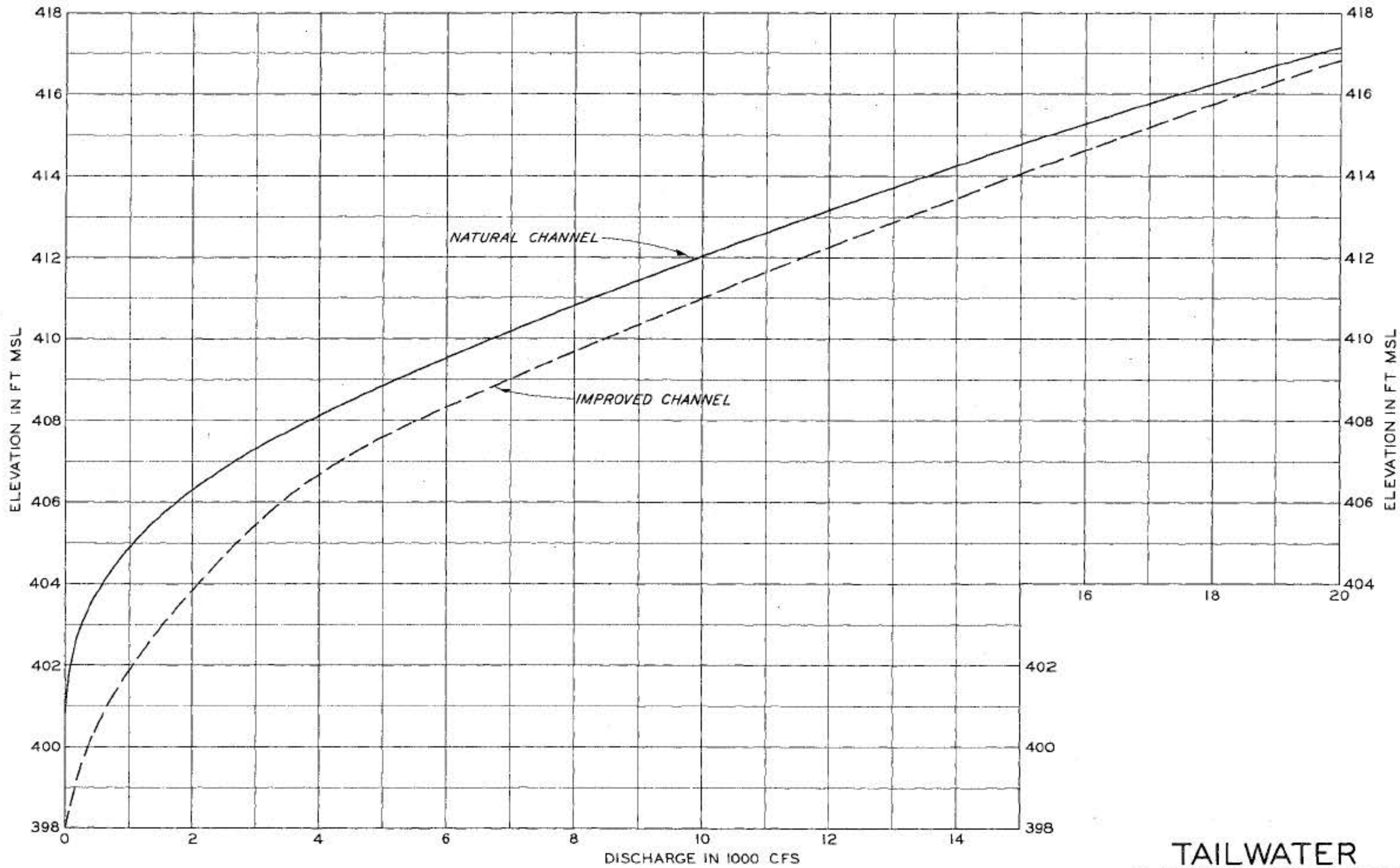
DETAILS OF CONDUIT



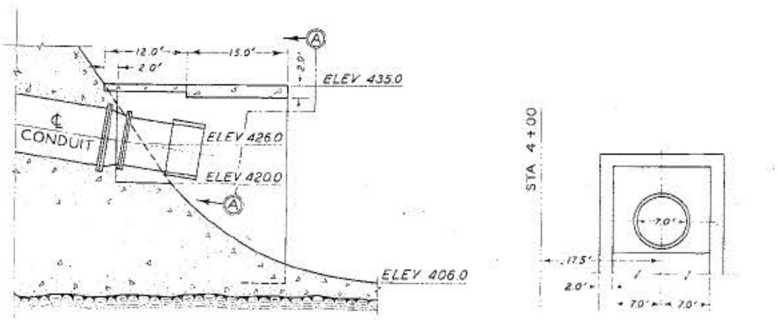
0.1093'
0.0729'
0.0208' RADIUS
0.2917' RADIUS
SECTION B-B
0.0052' GASKET
1.667'
11.250'
BRONZE LINER
0.0833'
7.000' DIA
8.313'
90°
2.792'
0.0729'
0.0729'
SECTION A-A
ELEVATION
VALVE DETAILS
SCALE
1 0 1 2 3 4 FT

PLATE 3

PLATE 4



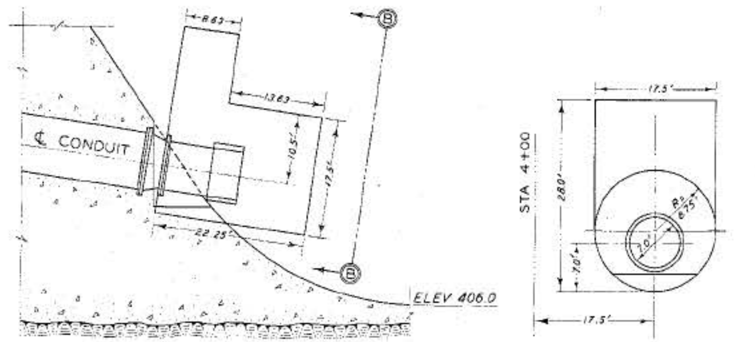
TAILWATER
RATING CURVES



SECTION THROUGH CENTERLINE OF CONDUIT

SECTION A-A

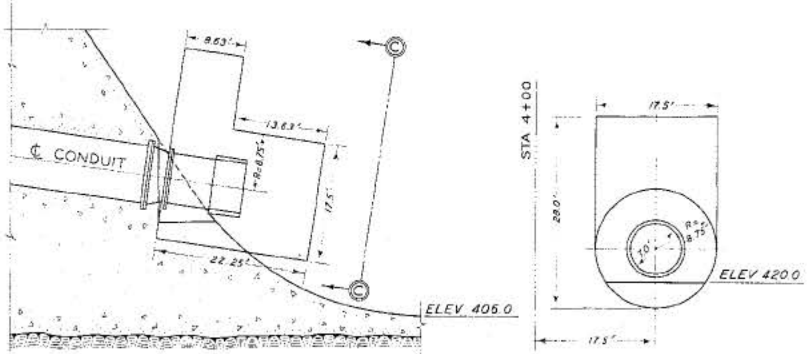
TYPE 1 HOOD



SECTION THROUGH CENTERLINE OF CONDUIT

SECTION B-B

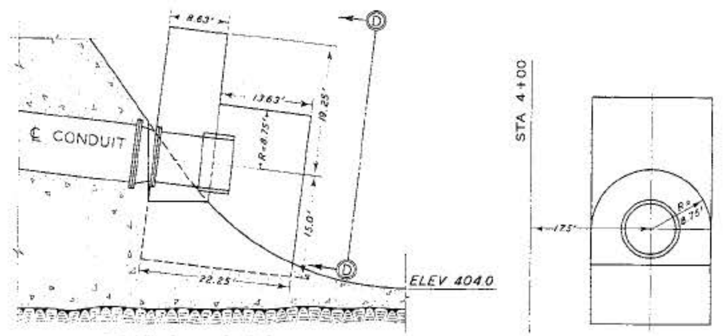
TYPE 2 HOOD



SECTION THROUGH CENTERLINE OF CONDUIT

SECTION C-C

TYPE 3 HOOD



SECTION THROUGH CENTERLINE OF CONDUIT

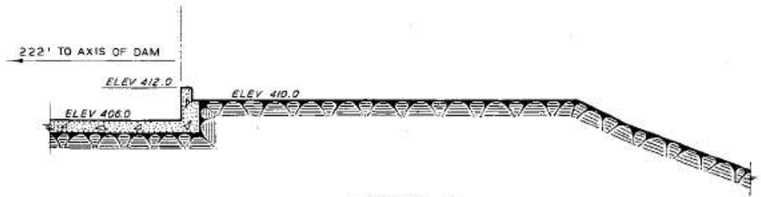
SECTION D-D

TYPE 4 HOOD

HOOD DESIGNS

PLATE 6

ORIGINAL



TYPE 3

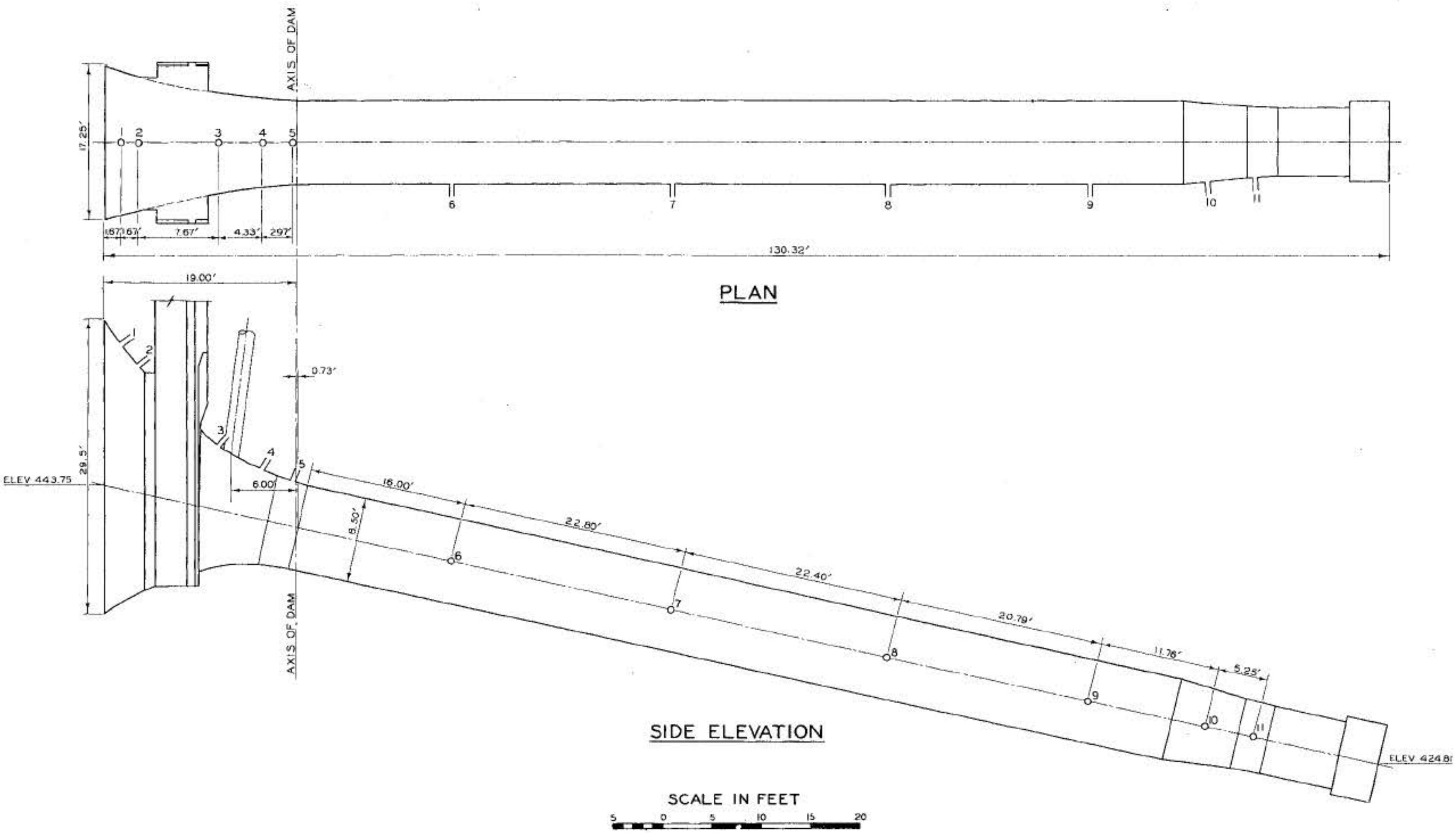
TYPE 2

TYPE 4

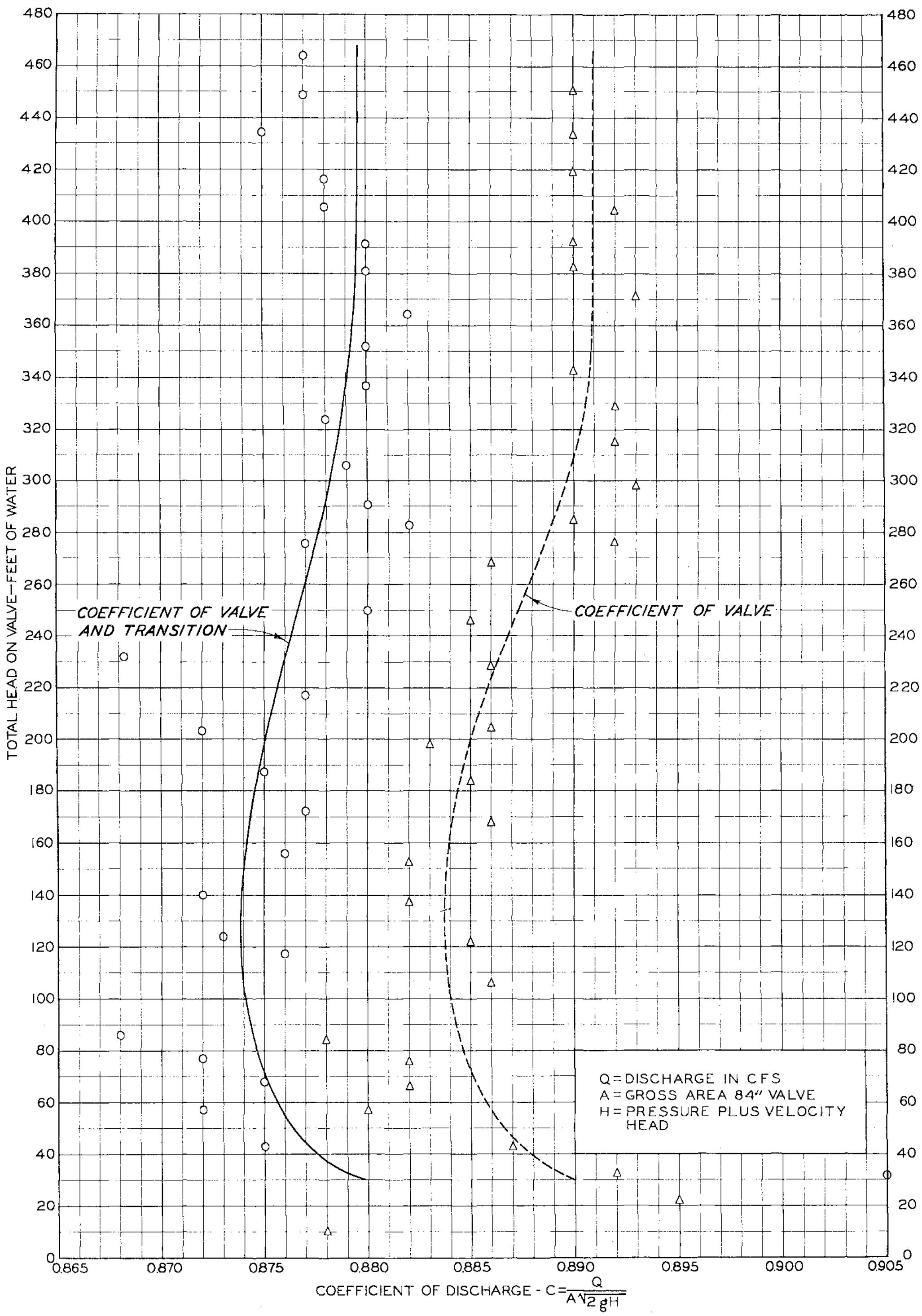
NOTE: TYPE 5 AND 6 SAME AS TYPE 4
EXCEPT TYPE 5 HAS 8.0 FT SILL
AND TYPE 6 HAS 10.0 FT SILL.

PROFILES OF EXIT AREAS

PLATE 7

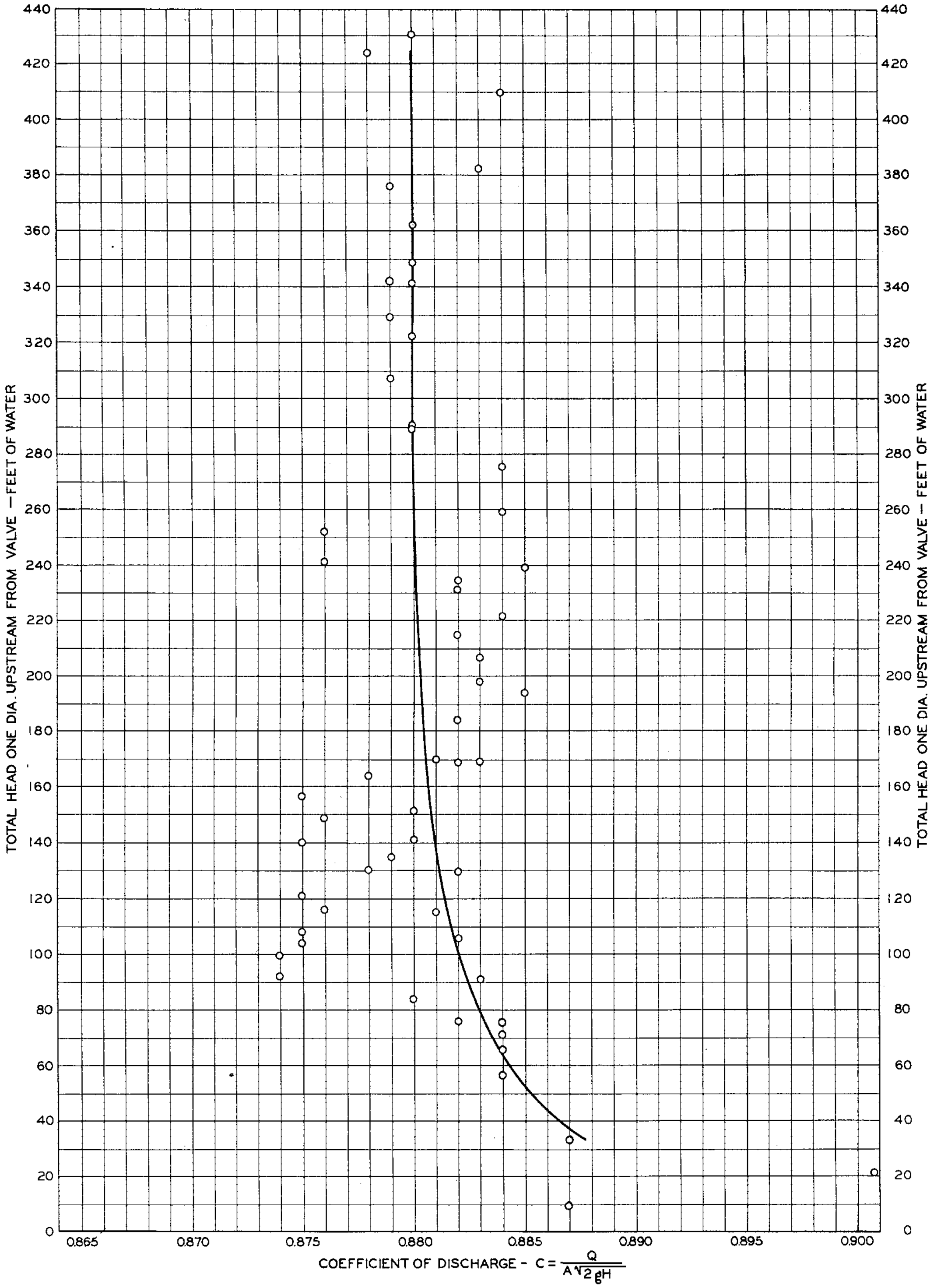


PIEZOMETER LOCATIONS



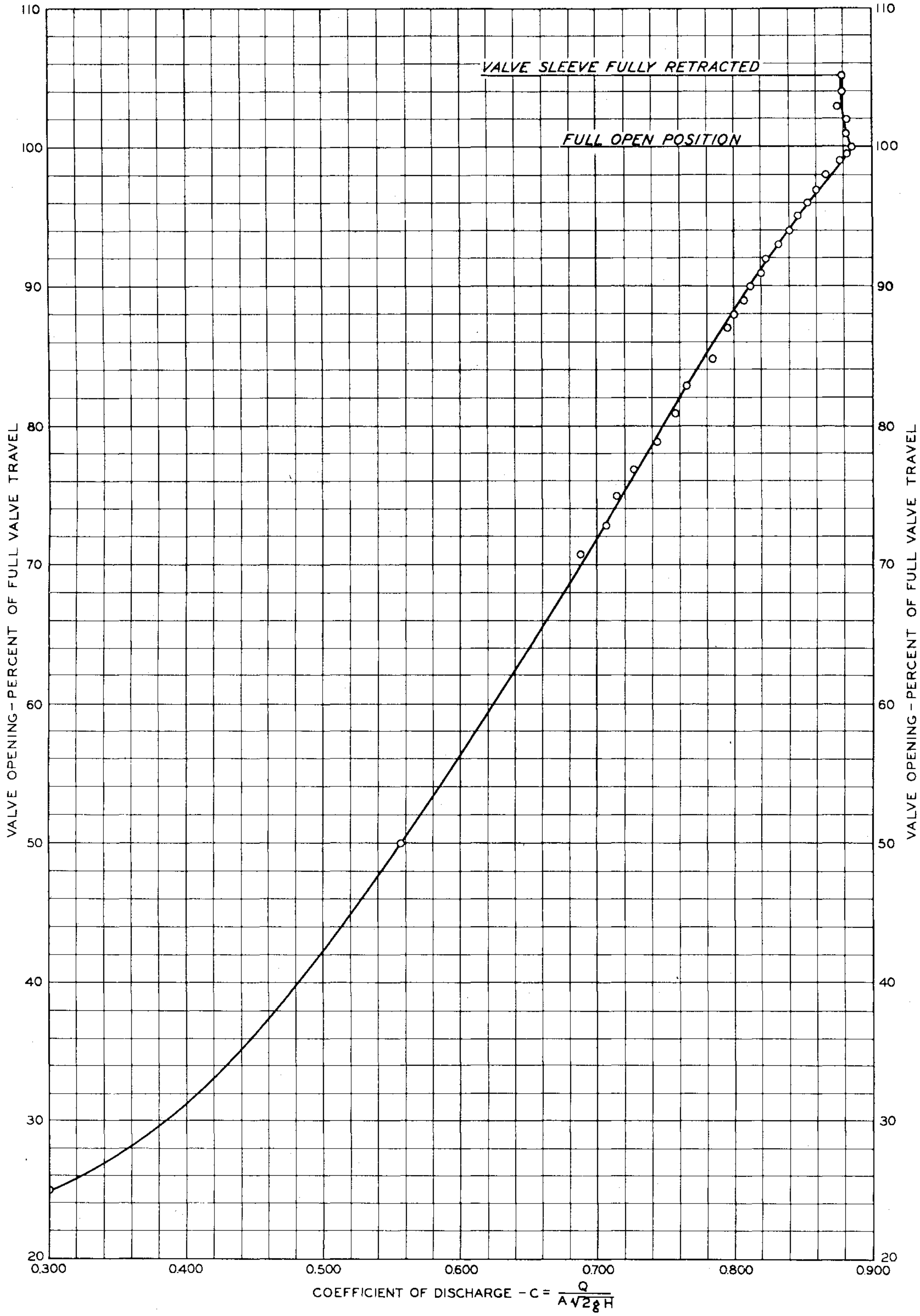
NOTE: DISCHARGE COEFFICIENT FOR VALVE AND TRANSITION CALCULATED FROM MEASUREMENTS ON PIEZOMETER 140 FT UPSTREAM FROM VALVE ON 102-INCH DIA. CONDUIT.
DISCHARGE COEFFICIENT FOR VALVE CALCULATED FROM MEASUREMENTS ON PIEZOMETER 2.0 FT UPSTREAM FROM VALVE

HEAD-COEFFICIENT CURVES
102-INCH CONDUIT WITH TRANSITION
84-INCH HOWELL-BUNGER VALVE
FULL VALVE OPENING



NOTE: Q=DISCHARGE IN CFS
A=AREA OF 84-INCH PIPE IN SQ FT
H=PRESSURE PLUS VELOCITY HEAD ONE DIA. UPSTREAM OF VALVE IN FEET OF WATER

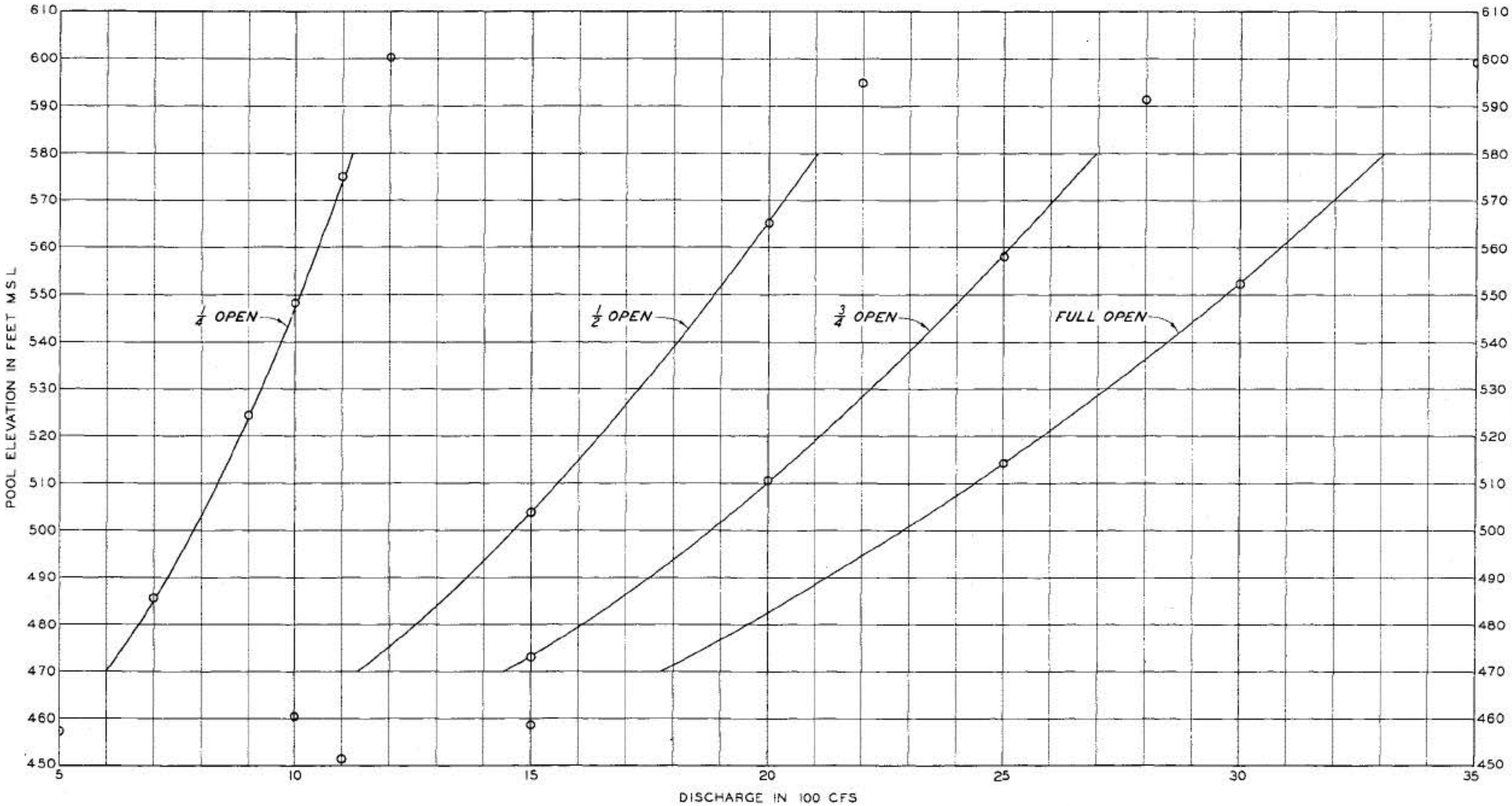
HEAD – COEFFICIENT CURVE
84-INCH CONDUIT
84-INCH HOWELL – BUNGER VALVE
FULL VALVE OPENING



NOTE: Q DISCHARGE IN C.F.S.
A AREA OF 84-INCH PIPE IN SQ. FT.
H PRESSURE PLUS VELOCITY HEAD ONE DIA. UPSTREAM OF VALVE IN FEET OF WATER.

VALVE OPENING VS COEFFICIENT
84-INCH CONDUIT
84-INCH HOWELL-BUNGER VALVE

PLATE 10

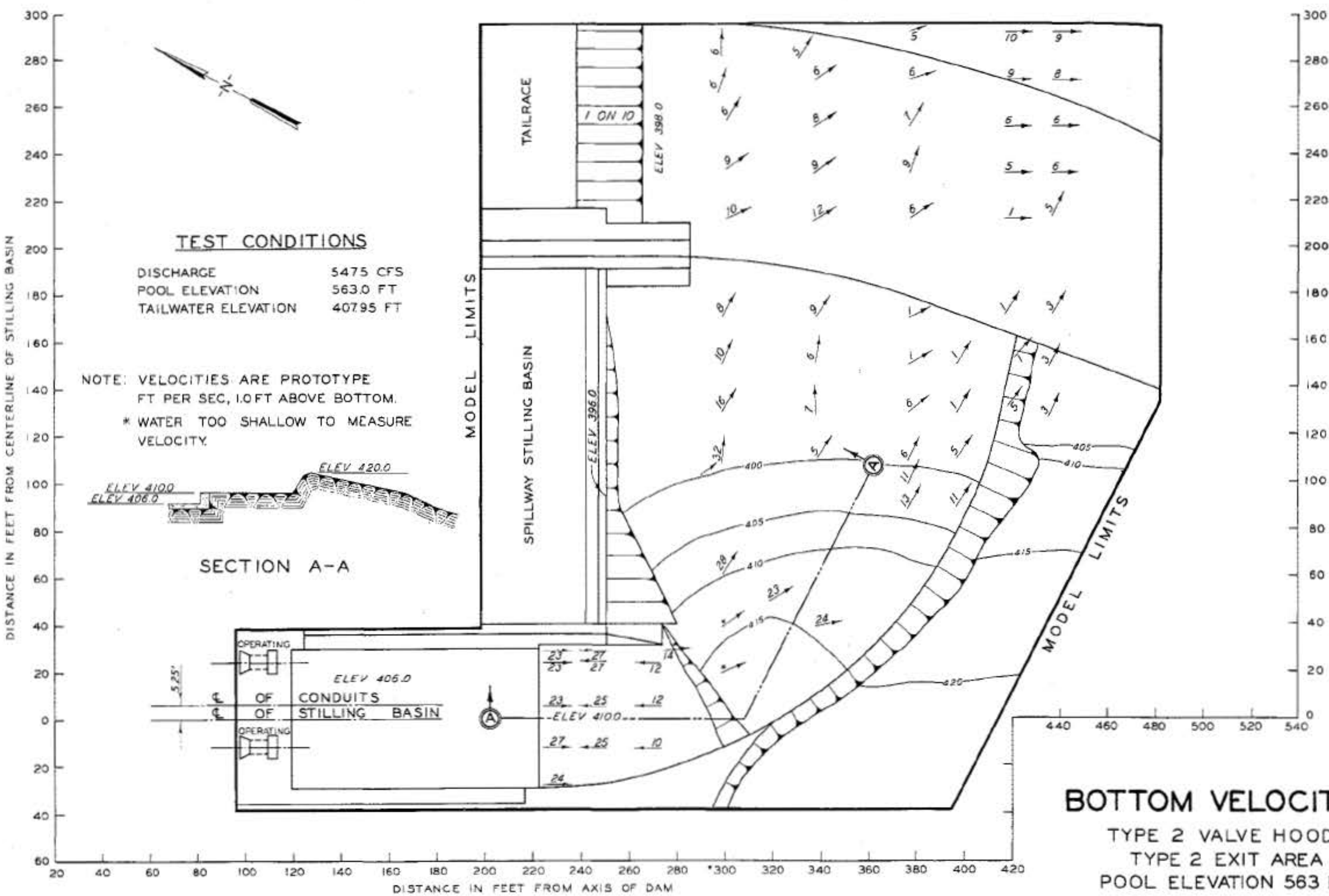


NOTE: RATING CURVE COMPUTED FROM DATA PRESENTED IN TABLE I AND ON PLATE 10.

RATING CURVES

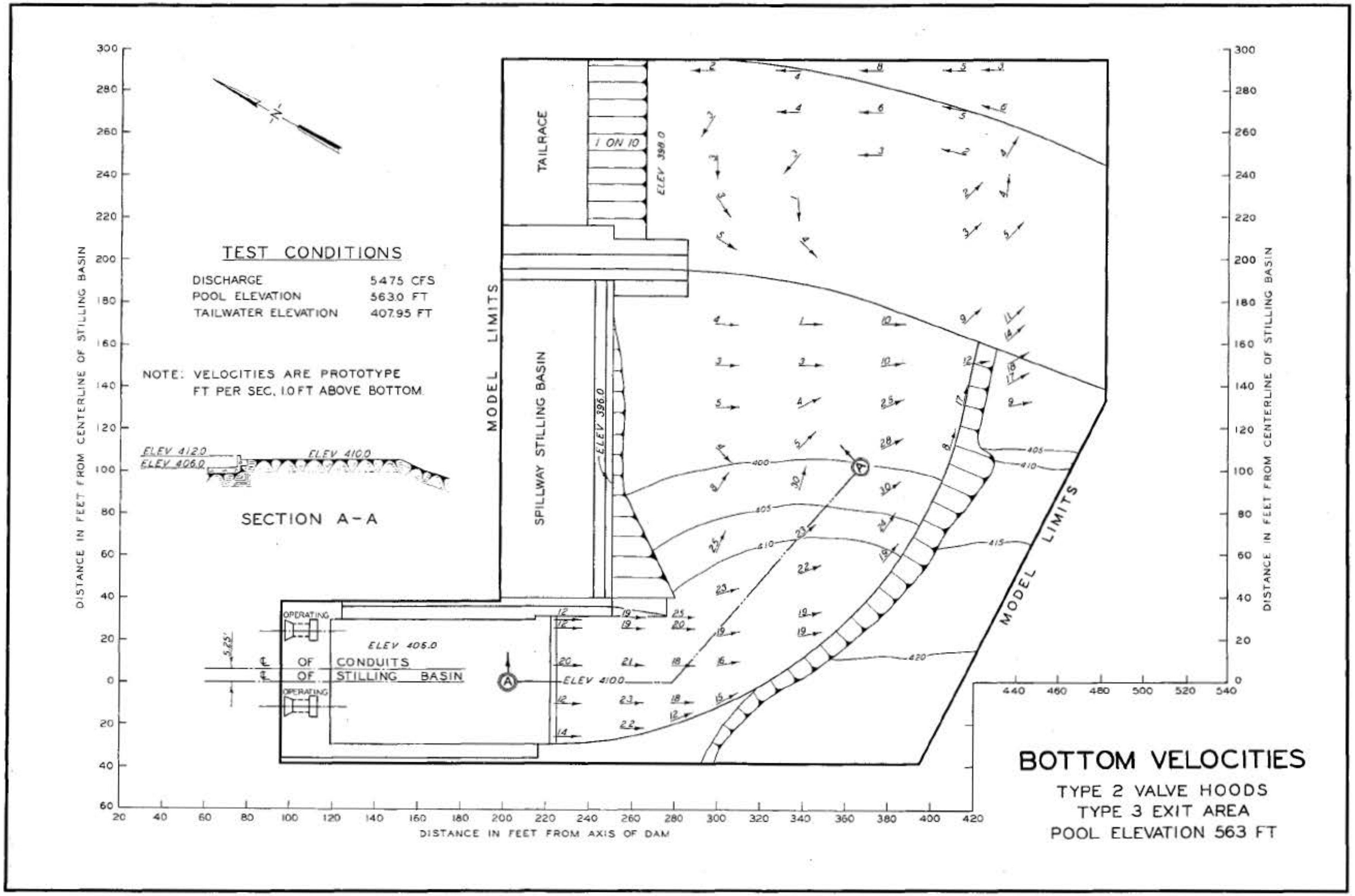
ORIGINAL CONDUIT AND VALVE
NO HOOD

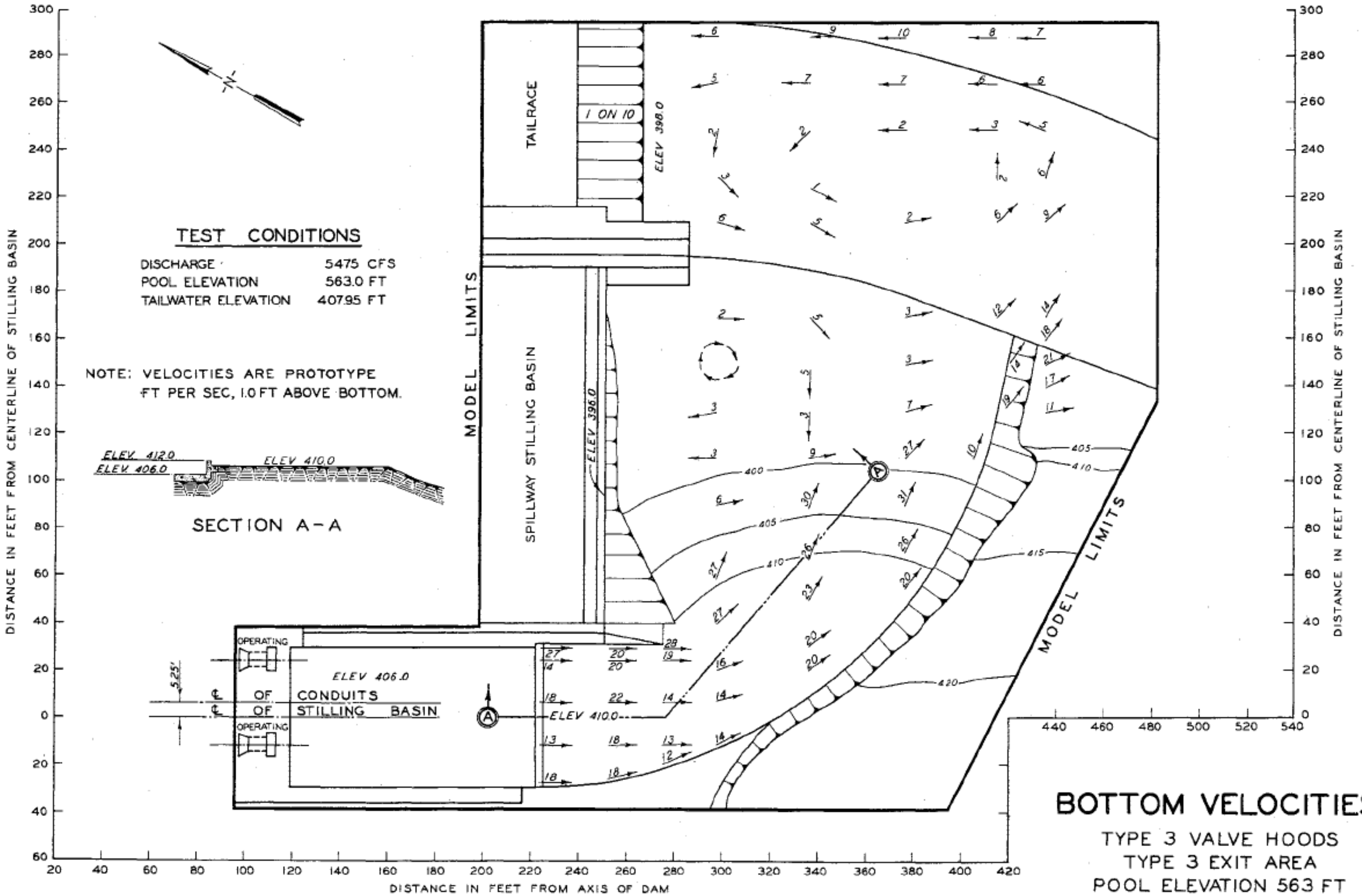
PLATE 12



BOTTOM VELOCITIES

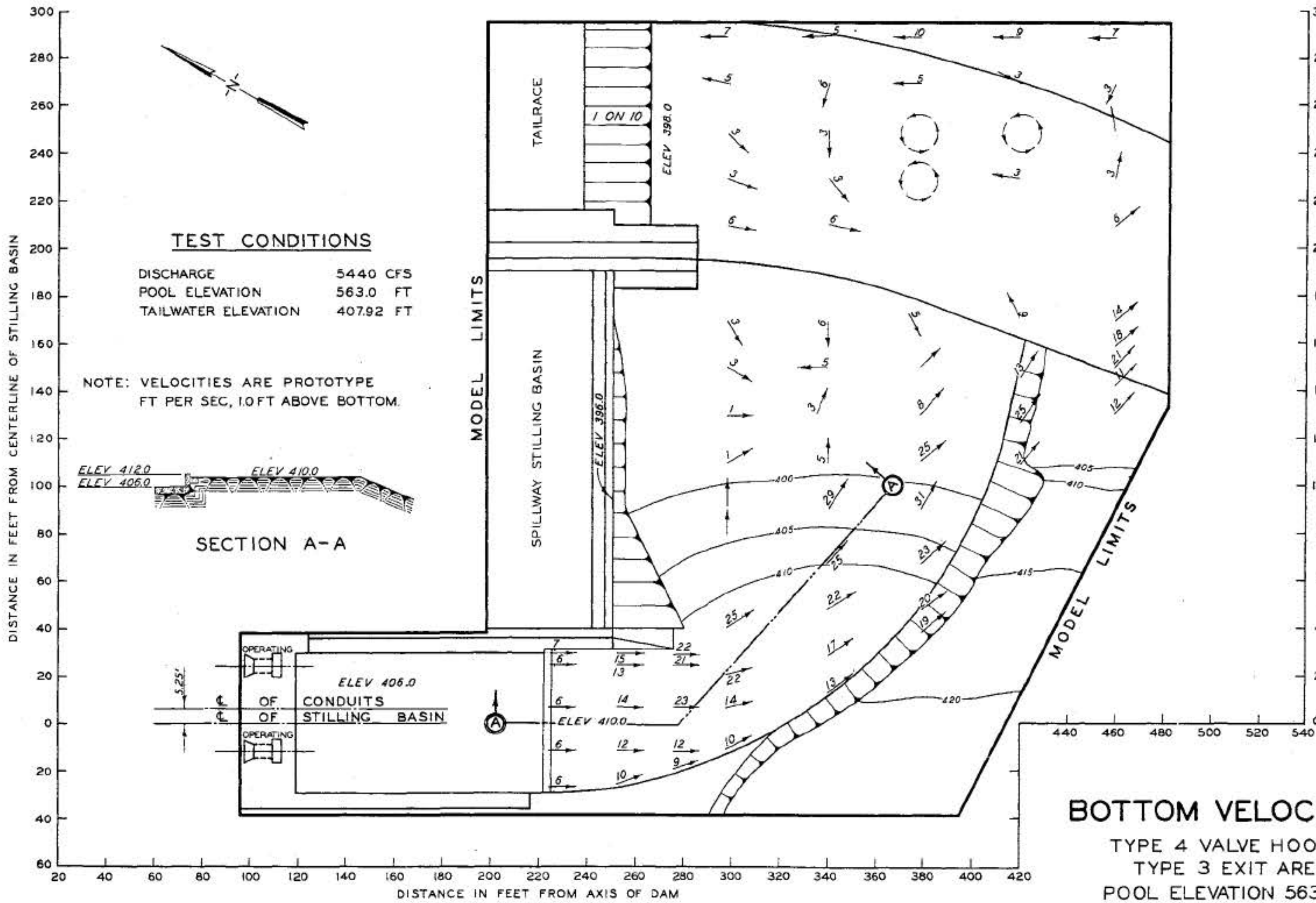
TYPE 2 VALVE HOODS
TYPE 2 EXIT AREA
POOL ELEVATION 563 FT


TEST CONDITIONS
DISCHARGE 5475 CFS
POOL ELEVATION 563.0 FT
TAILWATER ELEVATION 407.95 FT
NOTE: VELOCITIES ARE PROTOTYPE FT PER SEC, 1.0 FT ABOVE BOTTOM.
ELEV 412.0
ELEV 406.0
ELEV 410.0
SECTION A-A
TAILRACE
1 ON 10
ELEV 398.0
MODEL LIMITS
SPILLWAY STILLING BASIN
ELEV 396.0
ELEV 405.0
℄ OF CONDUITS
℄ OF STILLING BASIN
OPERATING
OPERATING
5.25'
ELEV 410.0
MODEL LIMITS
DISTANCE IN FEET FROM CENTERLINE OF STILLING BASIN
DISTANCE IN FEET FROM AXIS OF DAM
BOTTOM VELOCITIES
TYPE 2 VALVE HOODS
TYPE 3 EXIT AREA
POOL ELEVATION 563 FT



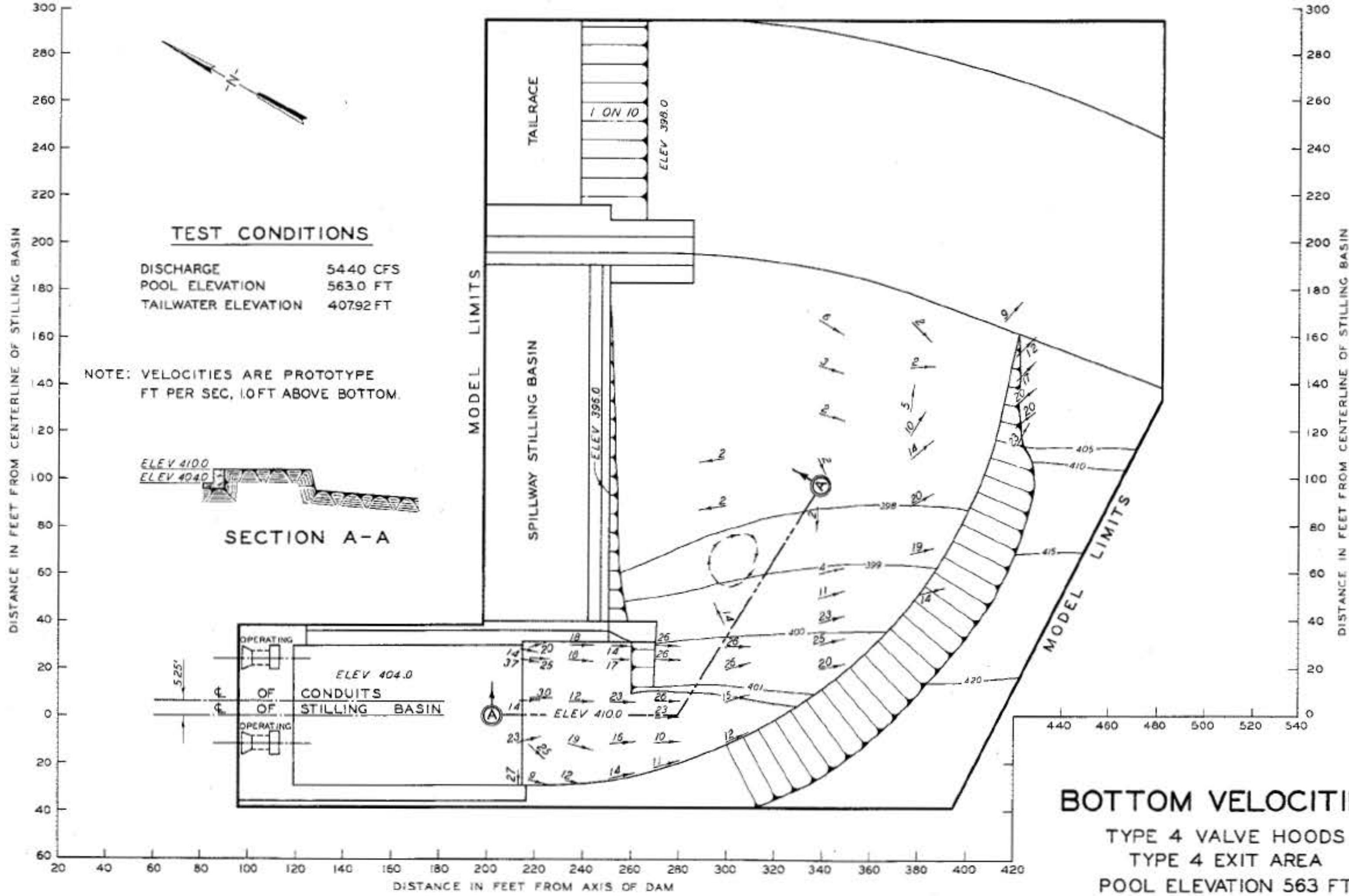
BOTTOM VELOCITIES

TYPE 3 VALVE HOODS
TYPE 3 EXIT AREA
POOL ELEVATION 563 FT



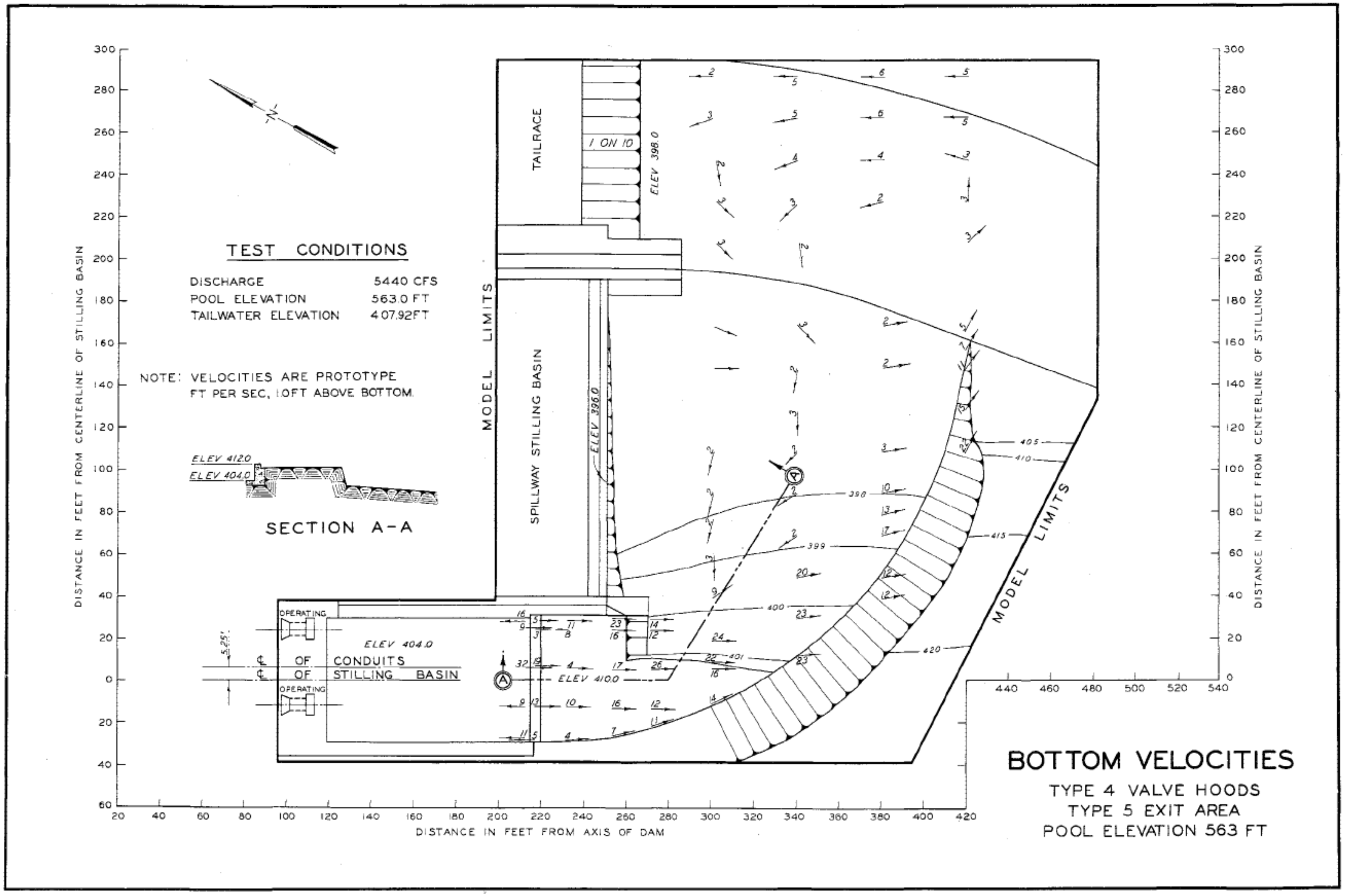
BOTTOM VELOCITIES

TYPE 4 VALVE HOODS
TYPE 3 EXIT AREA
POOL ELEVATION 563 FT



BOTTOM VELOCITIES

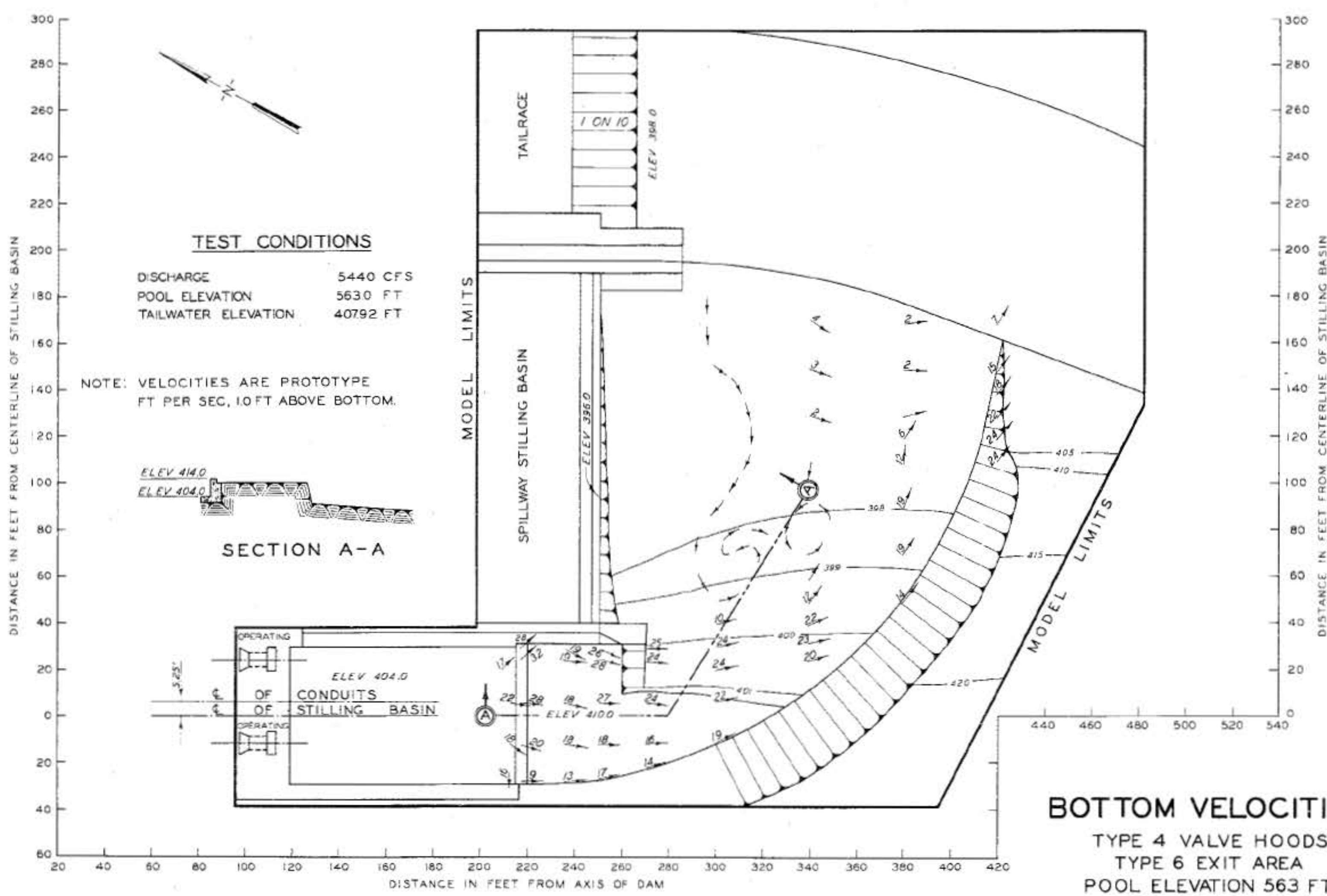
TYPE 4 VALVE HOODS
TYPE 4 EXIT AREA
POOL ELEVATION 563 FT



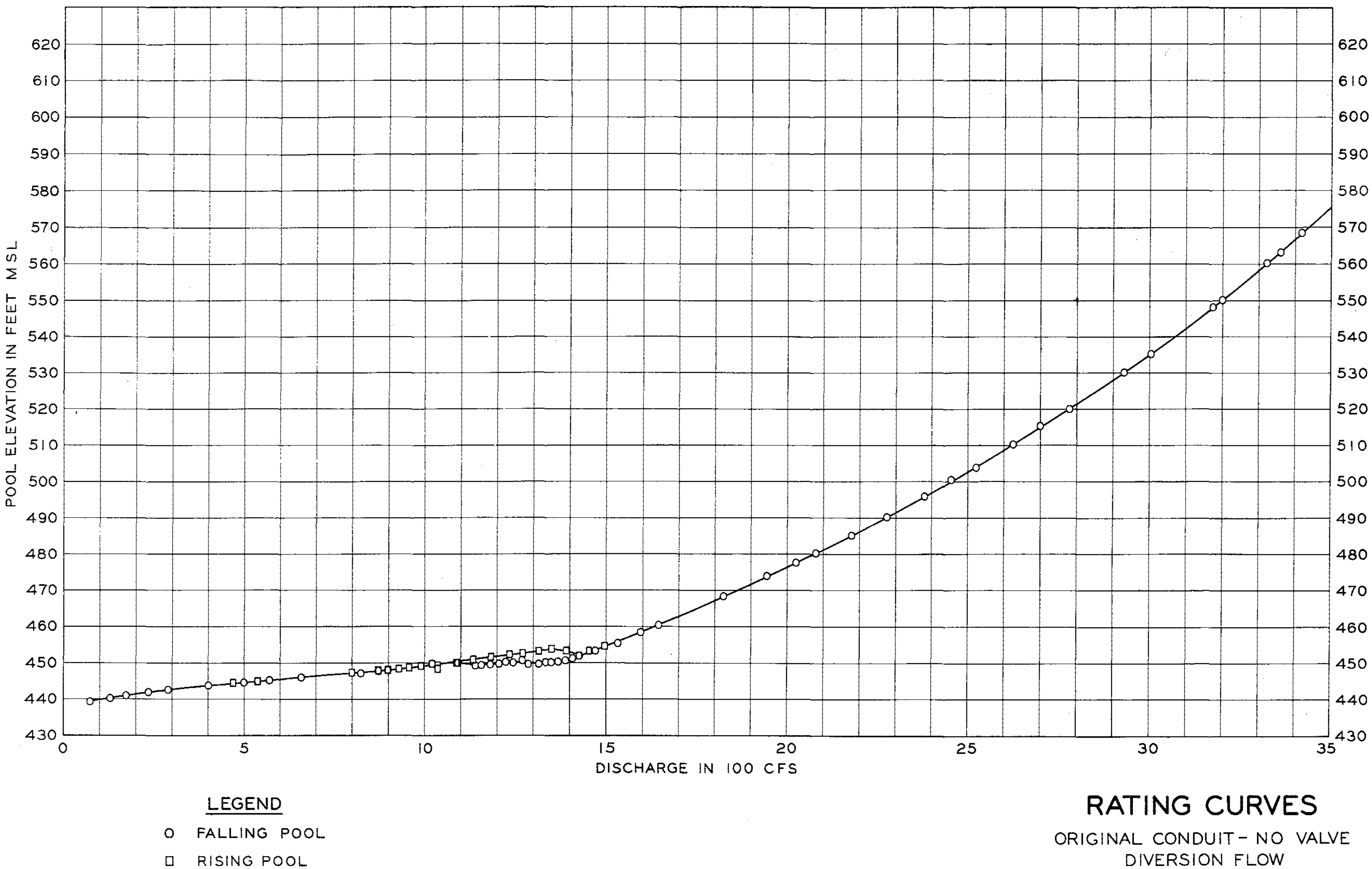
BOTTOM VELOCITIES

TYPE 4 VALVE HOODS
TYPE 5 EXIT AREA
POOL ELEVATION 563 FT

PLATE 17



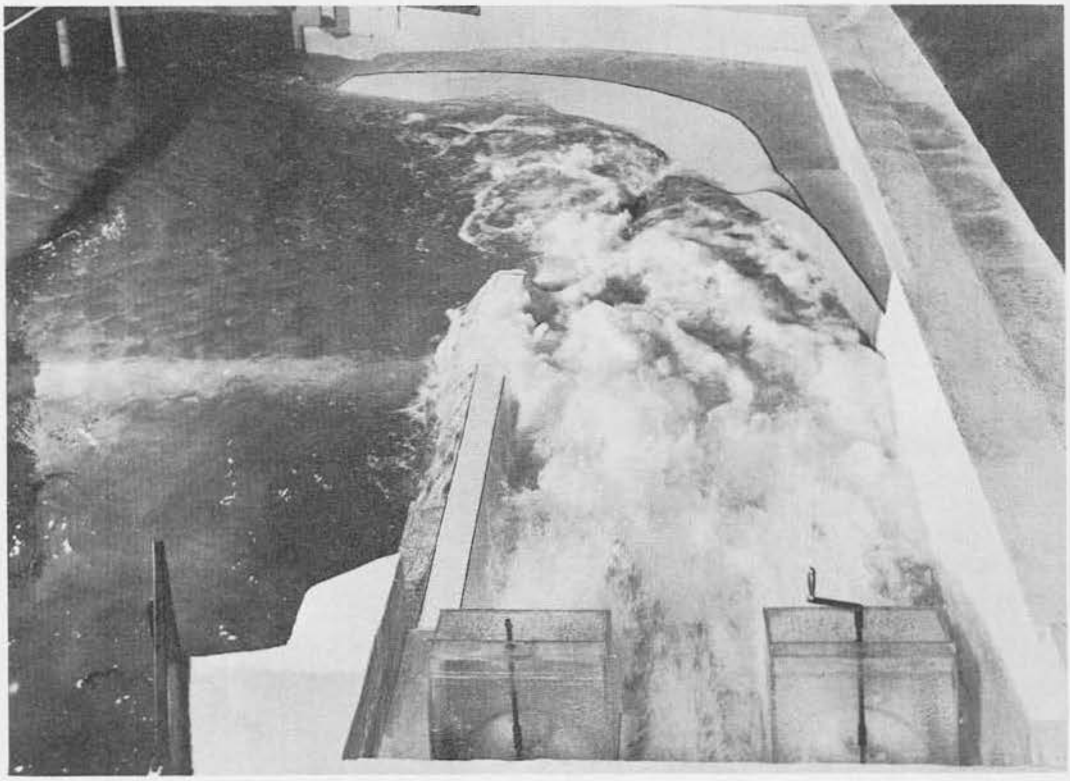
BOTTOM VELOCITIES
TYPE 4 VALVE HOODS
TYPE 6 EXIT AREA
POOL ELEVATION 563 FT

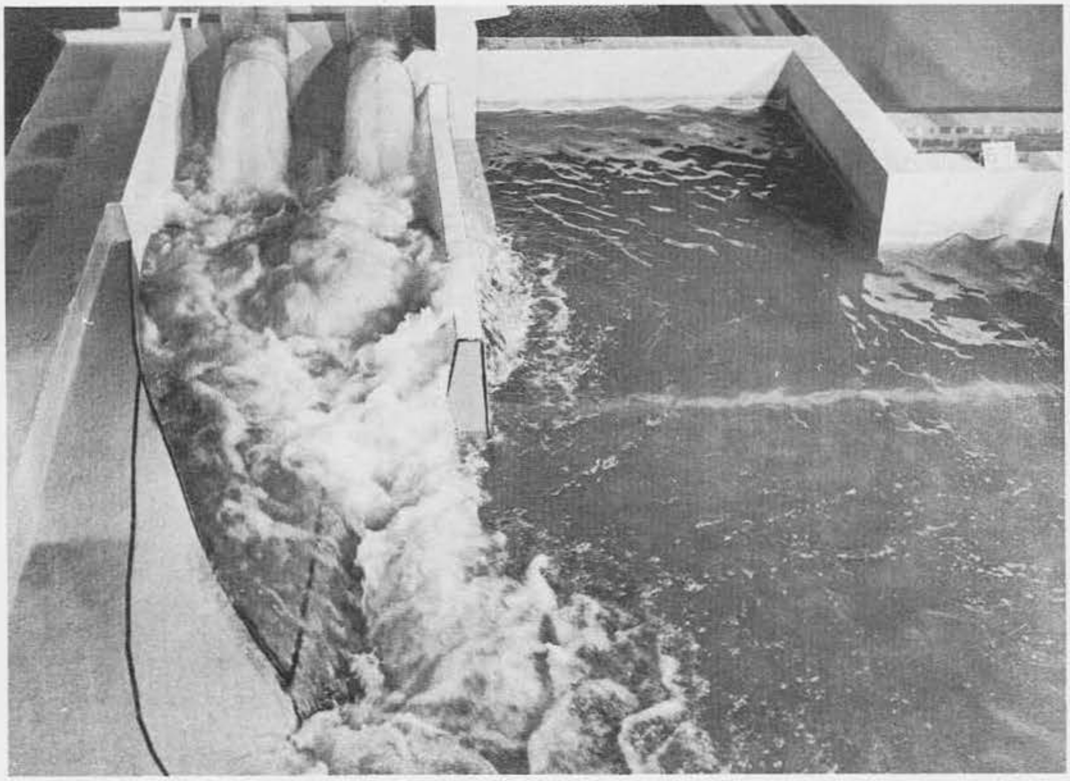


RATING CURVES

ORIGINAL CONDUIT – NO VALVE
DIVERSION FLOW

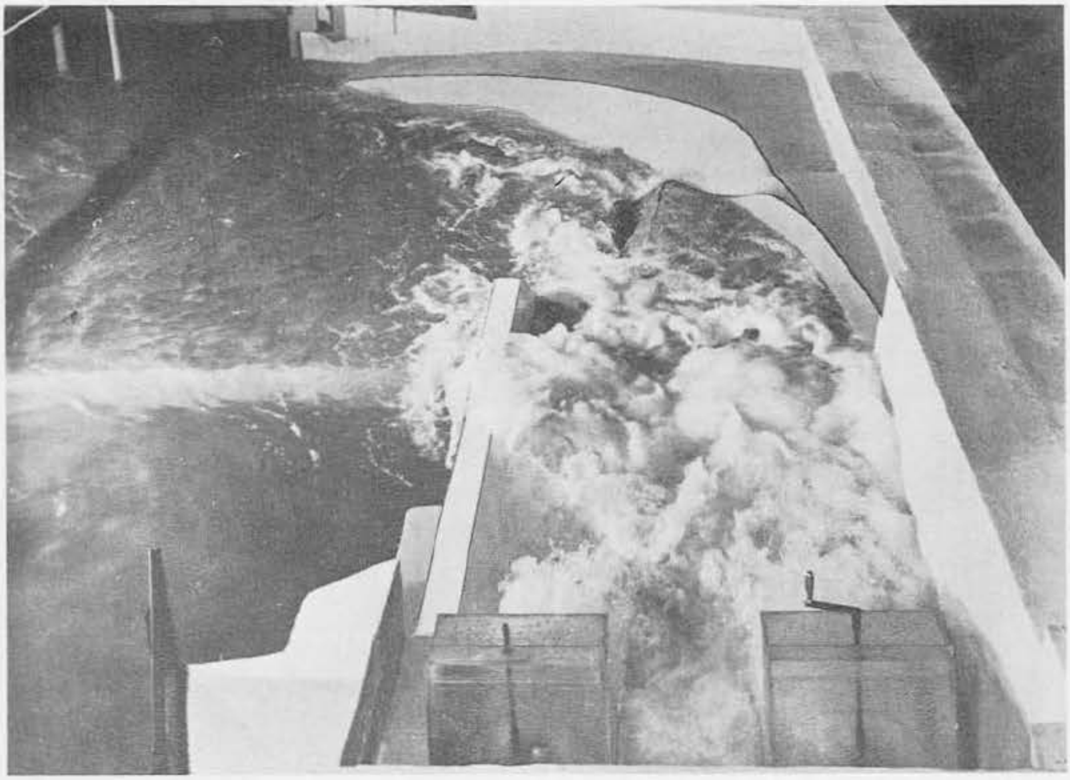
APPENDIX

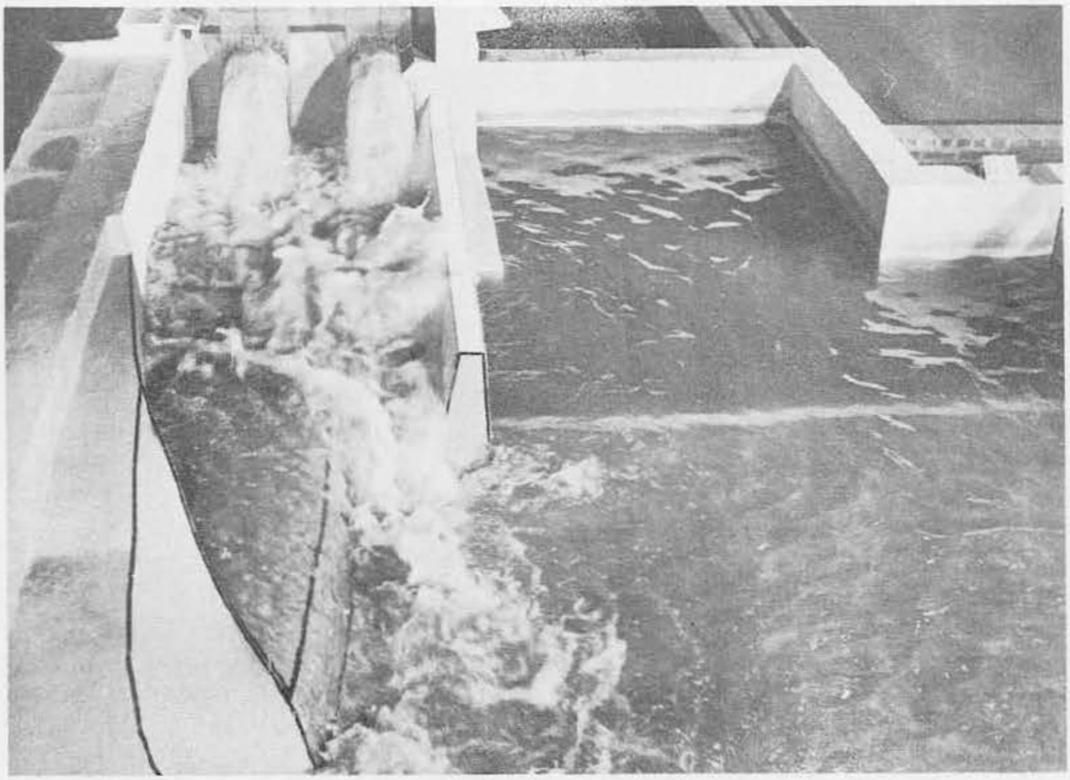




Pool 548; discharge 5140 cfs; tailwater elev 407.7

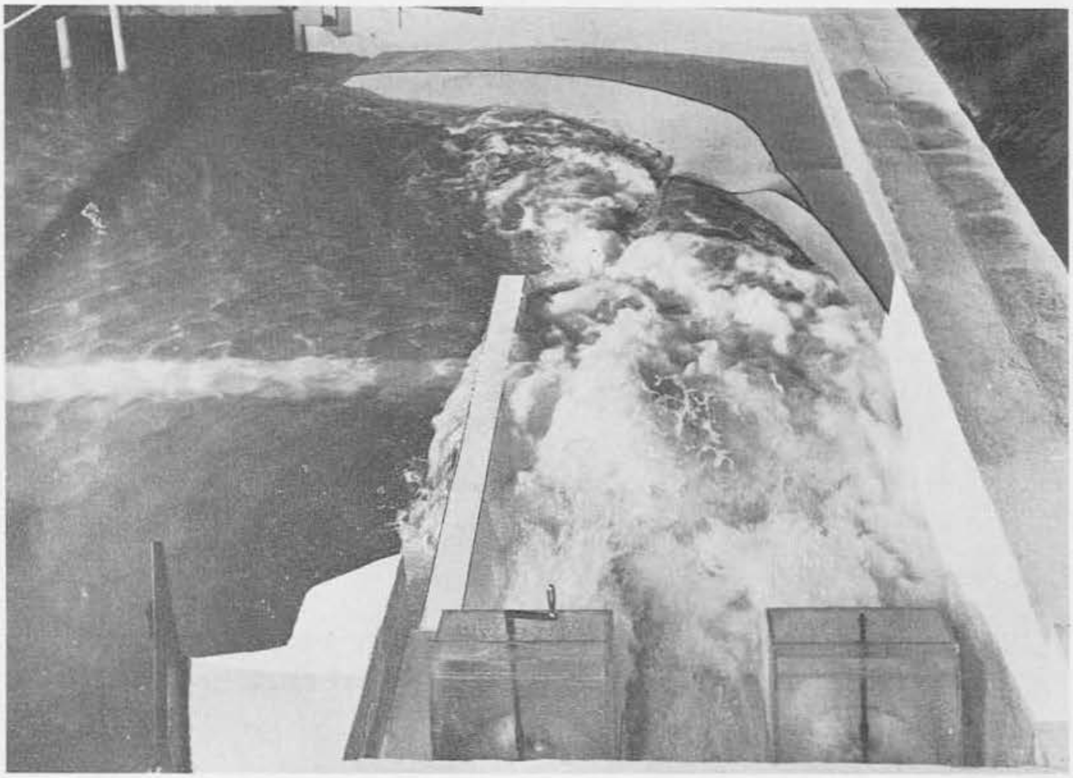
Photograph 1. Type 4 hoods - type 5 exit. Valves full open.

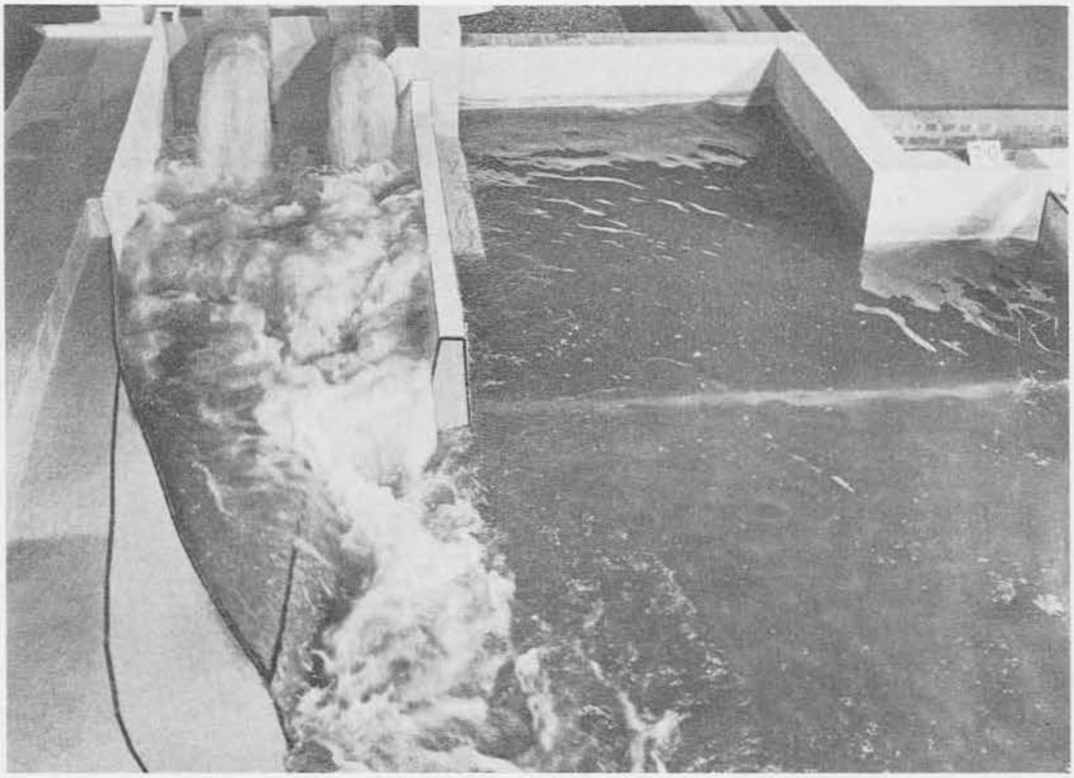




Pool 504; discharge 4050 cfs; tailwater elev 406.3

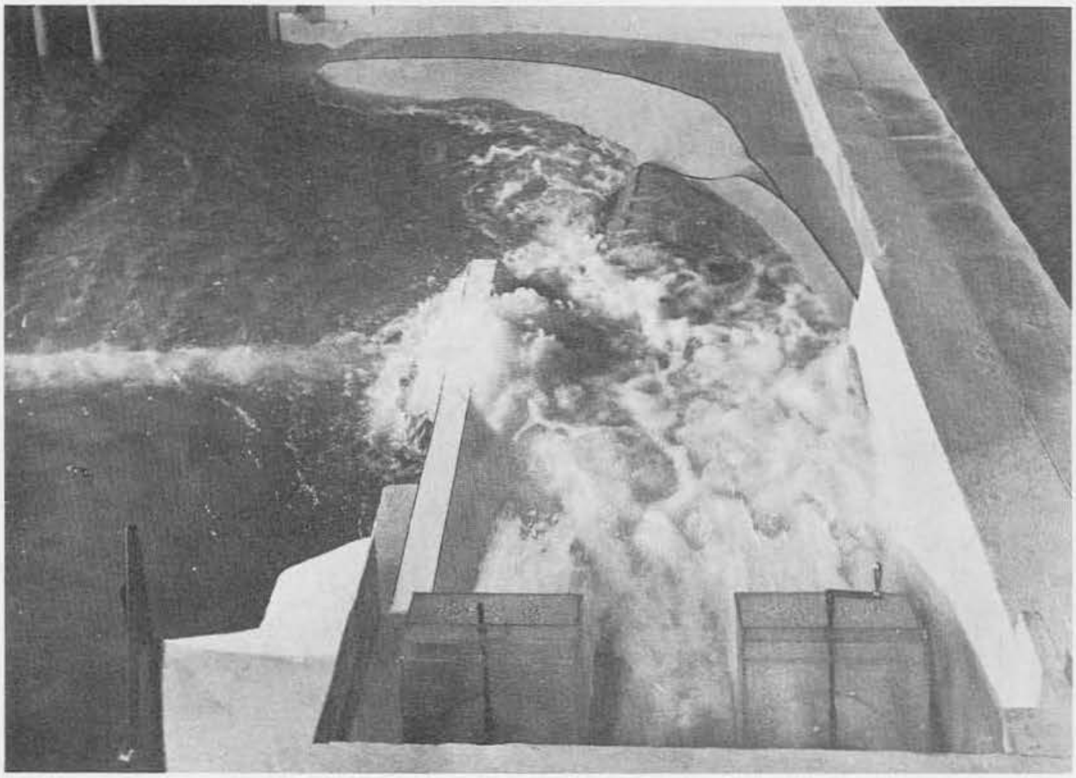
Photograph 2. Type 4 hoods - type 5 exit. Valves full open.

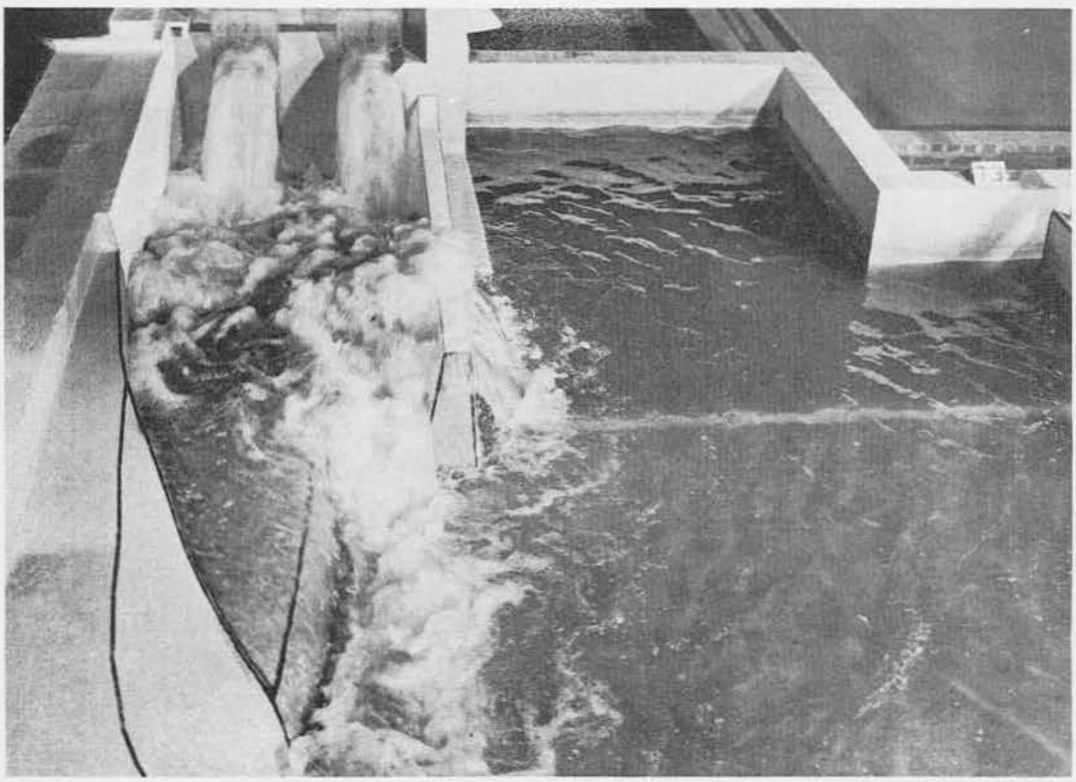




Pool 548; discharge 4510 cfs; tailwater elev 407.1

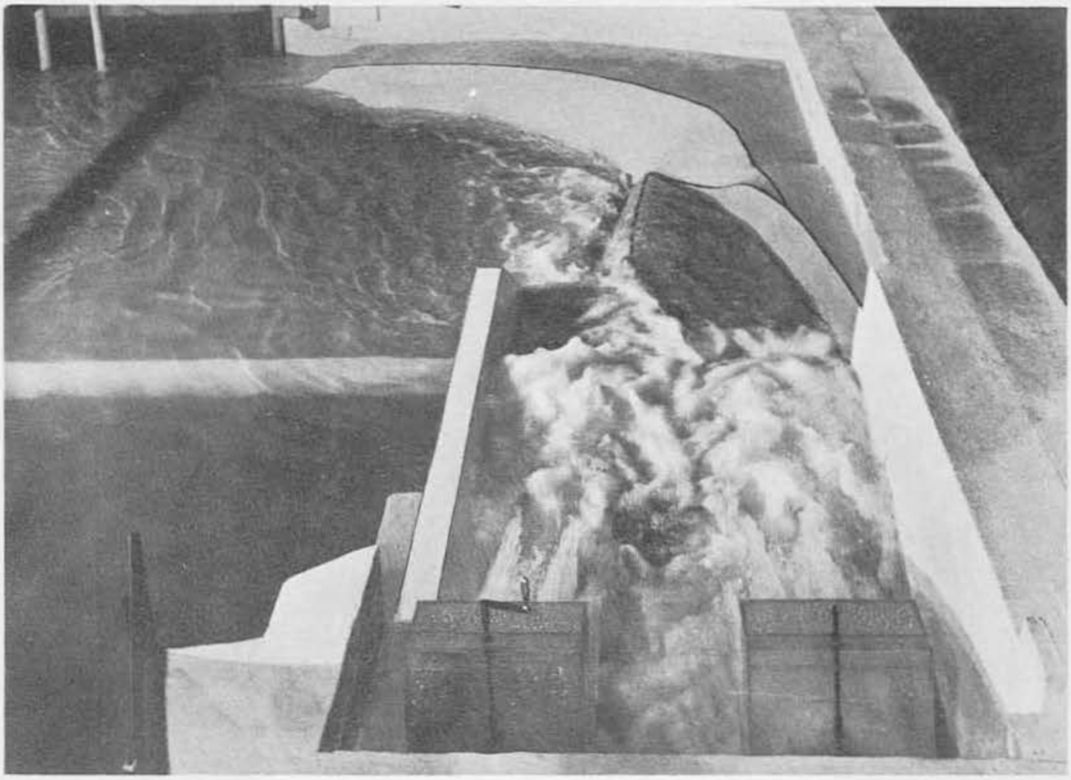
Photograph 3. Type 4 hoods - type 5 exit. Valves 3/4 open.

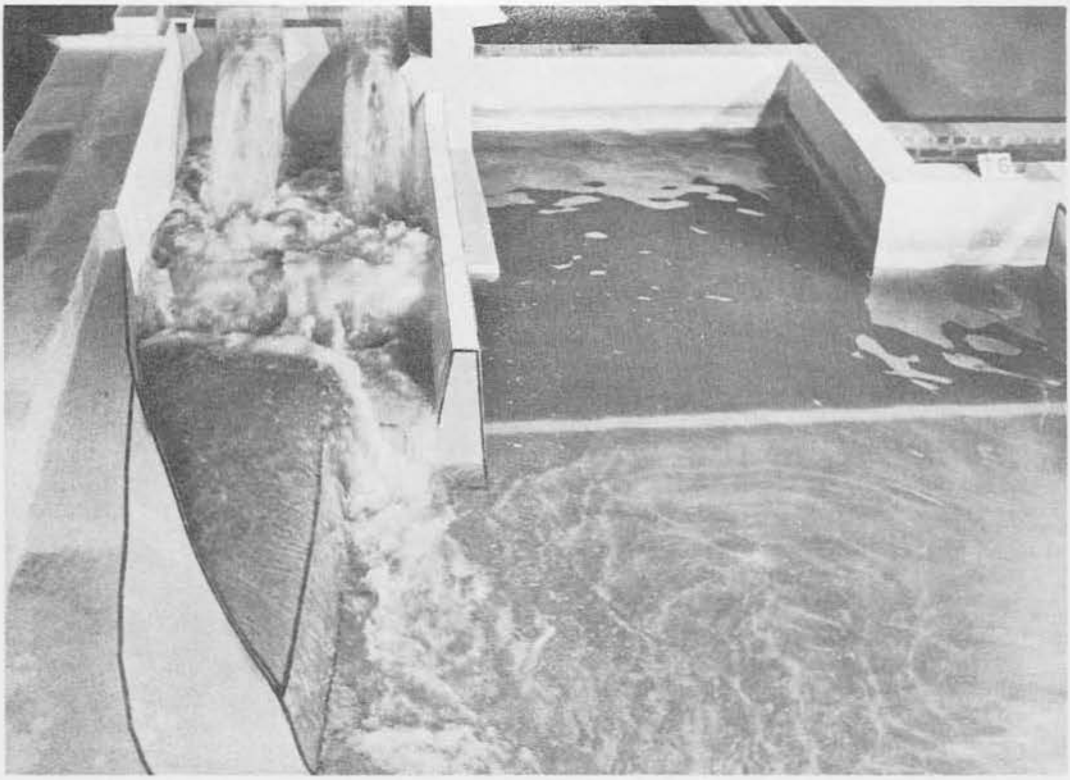




Pool 548; discharge 3440 cfs; tailwater elev 406.1

Photograph 4. Type 4 hoods _ type 5 exit. Valves 1/2 open.





Pool 548; discharge 2015 cfs; tailwater elev 403.8

Photograph 5. Type 4 hoods - type 5 exit. Valves 1/4 open.